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ORIGINAL ARTICLES

THE SIGNIFICANCE OF SULPHUR IN THE MANURING OF RICE

By S. P. Aiyar, Agricultural Chemist, Burma, New Delhi

(Received for publication on 24 May 1945)

(With Plate XIII and five text-figures)

LTHOUGH Sachs established that sulphur is an ssential element for plants in 1864 the importance f this element was not realized for a long time. uring the last thirty years there has been a great evival of interest in sulphur both as an essential utrient and as a soil ameliorant. The extensive terature on the subject has been reviewed by veral authors, notably by Hart and Peterson 911], Olson and St. John [1921], Nightingale, chermerhorn and Robbins [1932], Willis [1939], nd Balks [1939]. In a recent address to the merican Society of Agronomy, Alway [1940] onsidered it necessary to refer to sulphur as 'a utrient element slighted in agricultural research'.

A perusal of the literature reveals the fact that ractically nothing is known about the relation of ulphur to the rice crop. Katayama [1905] used ypsum as a source of calcium in certain tests with ce in sand culture but in presence of ammonium ulphate and other sulphates. Dobbs [1916], Sher- rd [1920] and Ghosh and Basu [1925] have re- orded the use of sodium sulphate, magnesium ulphate and calcium sulphate in the manuring of ce and legumes in South Bihar. The importance f sulphur in the manuring of rice has been pointed ut in recent publications [Aiyar, 1937, 1944, 1945]. Storey and Leach's discovery [1932] that 'tea ellows' is a disorder caused by sulphur deficiency nd the studies of Martin [1934] on sugarcane, and f McMurtrey [1938] on tobacco on the effects of ulphur deficiency have served to emphasize the nportance of a study of the problem in relation other tropical crops.

reliminary observations

In connection with a study of various nitrogen rtilizers for rice on the heavy clay soil of Mandalay, urma, it was observed that plants treated with mmonium sulphate and Nicifos II were taller and a deeper green colour than plants treated with rea, cyanamide, ammonium bicarbonate or sodium trate which were distinctly chlorotic. The charac- ristics of these chlorotic plants have been described sewhere [Aiyar, 1945] but are again referred to re for the sake of clarity.

Compared to the normal healthy plants, the chlorotic plants had a well marked yellowish green colour which was more prominent in the younger leaves than in the older leaves, whereas in nitrogen deficiency the older leaves are more affected. Further, the height, leaf size and tillers were reduced in the affected plants. As the season advanced the chlorotic plants gradually assumed a deep green colour which was fully retained at the usual time of harvest in sharp contrast to the golden yellow colour of the mature normal crop. The yield of both straw and grain was greatly reduced in the chlorotic plants.

Although these observations pointed to the existence of a deficiency in the soil, it was necessary not only to eliminate alternative possibilities such as a deficiency of magnesium, nitrogen, or other nutrient but also to obtain direct evidence in order to conclude that the chlorotic symptoms were due to sulphur deficiency. The investigations involved in this work are described in the present article.

Methods and materials

Analytical methods

(1) *Total nitrogen.* This was determined by the Kjeldahl-Gunning Method.

(2) *Soluble nitrogen.* The fresh plant material was cut into small pieces and ground up with clean sand and a little water. The pulp was filtered through muslin and washed with water. The water extract was heated to boiling in a porcelain basin and the proteins coagulated by adding a little acetic acid. The liquid was then filtered on a Buchner funnel, the filtrate with washings transferred to a measuring flask, cooled, and the volume made up to 250 c.c. An aliquot portion was used for determining the soluble nitrogen content by the Kjeldahl-Gunning Method.

(3) *Protein nitrogen.* The difference between the total nitrogen and soluble nitrogen was taken to be the protein nitrogen.

(4) *Total sulphur.* In plant material this was determined by a modification of the method of Warth and Krishnan [1935]. In the case of soil

the same procedure was followed except for the addition of 5 gm. of ammonium bromide per 100 c.c. of nitric acid reagent used for the extraction. In the final extract in HCl the iron and aluminium were removed by precipitation with ammonia. The precipitate was filtered and washed with hot water containing ammonium chloride. The sulphate was precipitated in the filtrate by barium chloride and weighed as barium sulphate.

(5) *Soluble sulphur.* The sulphate content of plant material was extracted by shaking 10 gm. of the powdered sample with 100 c.c. of water and one gm. of magnesium carbonate. The filtrate was shaken with activated charcoal and the sulphate precipitated in the clear extract with the usual precautions. The sulphate content of the soil was determined by extraction with water followed by precipitation as barium sulphate [Brown and Kellogg, 1915 ; Ames and Boltz, 1916].

(6) *Soluble sugars.* These were determined in a water extract of the plant material by the method of Eaton [1931].

(7) *Starch.* This was determined in the residue from the water extract by salivary digestion followed by hydrolysis with 2·5 per cent HCl [Eaton, 1931].

(8) *Chlorophyll.* Fresh leaves of equal age from plants with the various treatments were cut into small pieces and ground with clean sand and 95 per cent alcohol. The extract was decanted, and the grinding, extraction, and decantation were repeated until no more green colour could be extracted. The extract was made up to 100 c.c. with alcohol. Determination of the absolute amount of chlorophyll in the extract by colorimetric comparison with a solution of commercial chlorophyll proved unsuccessful. The determination of the 'blue component' in the extract by means of a tintometer outfit was also unsatisfactory. It was then decided to determine only the relative colour densities of the extracts by comparison among themselves using one of them as a standard. This method proved to be successful and convenient. It is well known that a change in treatment which affects the chlorophyll content causes a corresponding approxlmately proportionate change in all the other chloroplast pigments [Deuber, 1926 ; Fearon, 1940].

(9) *Ash constituents.* Five grams of the dried plant material were ashed in a muffle furnace and the ash treated with HCl. After removal of silica the HCl extract was made up to 100 c.c. Aliquot portions were used for the determination of P_2O_5, CaO, MgO, Fe_2O_3 and Mn by standard methods [Wright, 1940 ; A.O.A.C., 1940].

Characteristics of the soil

The soil of the Mandalay Farm is a greyish black heavy clay. The rice crop is grown with irrigation as the rainfall is only about 30 in. per annum. The main features of the soil are shown in Table I.

TABLE I

Characteristics of the Mandalay Farm soil

Items		0—12 in.
Mechanical analysis		
Coarse sand	per cent	4·1
Fine sand	„ „	22·0
Silt	„ „	24·0
Clay	„ „	45·3
$CaCO_3$	„ „	0·4
H_2O	„ „	4·2
Chemical analysis		
Organic carbon	per cent	0·42
Organic nitrogen	„ „	0·05
Total P_2O_5	„ „	0·05
Available P_2O_5	„ „	0·006
Available K_2O	„ „	0·020
Exchangeable bases	„ „	30 m.e.
Soil reaction	„ „	*p*H 8·05

Methods of experimentation

Since the chlorosis appeared to be a field problem pot culture work was not considered suitable for its study. There was no certainty of getting the chlorosis in pots and moreover it was anticipated that a disturbance of the soil by removing it from the field might interfere with the factors causing the disorder.

The first experiment was laid down in a field which had shown chlorosis in previous seasons. Although the crop showed marked response to treatments there was no uniformity in the plots and ultimately the yield data did not show significant differences. Accordingly further experiments were arranged on fairly uniform patches after the chlorosis had developed. These experiments were all carried out with due regard to statistical requirements but the details of working are not now available as they were lost through enemy action in Burma.

The experimental work had to be distributed over several seasons but the same selected variety of rice, Shwe-at, was used throughout.

Observations were made on the plants to study the nature of the response to different treatments, particularly in development and yield. The crop was analysed to obtain correlation of yield with composition, and to obtain evidence in regard to the nature of the deficiency and of its effect on plant nutrition. The analysis was carried out on composite samples only.

EXPERIMENTAL RESULTS

Experiment I. This experiment, the earliest of the series, was laid down in the 1931-32 season in a

d in front of the Mandalay Farm office, where chlorosis had been regularly observed during three previous seasons. The treatments which re made before transplanting included magnesium ide, magnesium chloride and magnesium sulate with and without ammonium phosphate ee from sulphate). The rates of application were lb. of P_2O_5, 30 lb. of N, 35 lb. of S, and 44 lb. MgO per acre. The experiment was laid out the form of randomized blocks with five replicans.

The treated plots soon showed that chlorosis not appear wherever sulphate was present and t the plants in all other plots were chlorotic. is observation was strengthened by treating orotic patches with dilute sulphuric acid in ten dely scattered spots in the Farm area. In every e the plants recovered and became completely rmal. There was thus left no doubt that a ficiency of magnesium, phosphate or nitrogen s not responsible for the chlorosis and that sulate deficiency was the most probable cause.

The crop samples obtained in this experiment re analysed and the data are shown in Table

TABLE II

mposition of rice plants treated with various magnesium compounds (percentage on oven dry basis)

Treatment	Appearance of plants	Straw			Grain	
		per cent N	per cent P_2O_5	per cent S	per cent N	per cent P_2O_5
-	Chlorotic . .	0·85	0·25	0·062	1·22	0·62
)	Chlorotic . .	0·91	0·24	0·068	1·34	0·65
Cl_2	Chlorotic . .	0·88	0·28	0·065	1·28	0·66
SO_4	Pure green . .	0·38	0·24	0·133	1·01	0·64

The curative effect of sulphate was confirmed in bsequent seasons by the Mycologist, Burma 33] and the Agricultural Chemist, Burma [1934], o tested the effect of various metallic salts inding the minor elements, magnanese, iron and pper.

Experiment II. During the seasons 1934-37 psum was applied to the chlorotic plots as a rrective on the field scale near the southern boundry of the Farm, and again the trouble was overne. The treatment was at the rate of 40 lb. of phur per acre with four replications. Large reases in yield were obtained and the crop bene normal in appearance and composition. The ta of a sample harvest are shown in Table III, h harvested unit having an area of 216 sq. ft.

TABLE III

Yield and composition of rice plant treated with gypsum (Percentages on oven dry basis)

Treatment	Straw			Grain		
	Mean yield per plot (lb.)	Per cent N	Per cent P_2O_5	Mean yield per plot (lb.)	Per cent N	Per cent P_2O_5
Nil . .	6·5	1·10	0·21	5·3	1·30	0·59
$CaSO_4$.	17·8	0·38	0·20	12·6	0·95	0·60

From Tables II and III the remarkable fact follows that the rice plant suffering from sulphate deficiency accumulates nitrogen to an enormous extent in the straw as well as in the grain. Previous experience had shown that the normal mature crop of Shwe-at, the variety of rice used throughout this work, contained 0·35 to 0·42 per cent of nitrogen in the straw and 0·90 to 1·10 per cent of nitrogen in the grain. The existence of abnormality may be inferred if the nitrogen content exceeds the upper limits.

Experiment III. This experiment was carried out during the season 1937-38 in order to obtain further information on the problem of sulphate deficiency. Such information appeared to be important in view of the absence of any residual effect from an application of 40 lb. of sulphur per acre in the form of gypsum. It was also found that an application of 10 tons per acre of farmyard manure did not protect the crop against chlorosis even in the year of application. Applied sulphate was probably assimilated and reduced, and thus rendered ineffective by microbial action. The organic sulphur added in farmyard manure was apparently present in a very resistant form. Drainage of the field undertaken to aerate the soil was found to have no beneficial effect on the crop. The indication was, therefore, that sulphate should be added as such every year, at any rate, to the Mandalay Farm soil.

Gypsum was again applied at 40 lb. of sulphur per acre on selected chlorotic patches which were converted into plots for this experiment in the south-east corner of the Farm area, east of the water course. Nitrogen, phosphoric acid and calcium were also applied at equivalent rates for comparison. The experiment was arranged in randomized blocks with four replications.

The effect of calcium sulphate was noticeable within three days after application. The treated chlorotic plants acquired a deep green colour and within a fortnight made rapid growth. Eventually these plants were even superior to the healthy plants in the adjacent field. There was no appreciable

change in the plants receiving the other treatments except for small patches of green colour due to partial recovery. The treatments and yields are shown in Table IV.

TABLE IV

Yield of rice straw and grain by treatment with gypsum and other chemicals

Treatment	Mean yield per plot of 315 sq. ft. in lb.		Straw/ Grain ratio
	Straw	Grain	
Nil	8·53	5·70	1·50
Urea	20·38	17·25	1·18
Primary calcium phosphate (pure)	17·22	12·81	1·34
Gypsum	39·75	21·34	1·82
Calcium chloride	10·34	6·34	1·65
Calcium nitrate	8·97	5·91	1·50
Critical difference for significance at P=0·05	5·82	3·65	

The yields shown in Table IV again demonstrate the powerful effect of sulphate. Straw production appears to be stimulated by sulphate. The treatment with urea and primary calcium phosphate also gave fairly large increases in yield. It is probable that a deficiency of nitrogen and phosphoric acid existed in some of the plots. There was also the possibility that all the plots did not have uniform sulphate deficiency. At the time of harvest the sulphate treated plants were fully ripe and golden yellow in colour whereas the plants in all other treatments were quite green and immature.

For further confirmation, samples of healthy and chlorotic plants were taken from the field and placed in culture solutions with and without sulphate. The chlorotic plants soon recovered and made normal growth in the presence of sulphate while both sets of plants failed to grow in the absence of sulphate (Plate XIII, fig. 1).

Plant samples were collected from all the plots in this experiment at different stages of growth and analysed for nitrogen, phosphoric acid and sulphur. The data are shown in Table V.

TABLE V

Composition of differently treated rice plants at different stages of growth

Date of sampling	Treatment	Roots		Straw			Grain		
		Per cent N	Per cent P_2O_5	Per cent N	Per cent P_2O_5	Per cent S	Per cent N	Per cent P_2O_5	Per cent S
10th September	Untreated-chlorotic	1·330	0·416	2·348	0·663	0·034			
	Untreated-healthy	1·526	0·491	2·352	0·713	0·094			
24th September	Untreated-chlorotic	1·202	0·508	2·282	0·628	0·040			
	Untreated-healthy	1·078	0·388	2·240	0·658	0·095			
	Urea	1·190	0·378	2·072	0·618	..			
	Ca $(H_2PO_4)_2$	1·036	0·383	1·862	0·700	..			
	Ca SO_4	1·106	0·421	2·280	0·593	0·125			
	Ca Cl_2	1·062	0·476	2·100	0·673	..			
	Ca $(NO_3)_2$	1·084	0·443	1·736	0·638	..			
25th October	Untreated-chlorotic	..	..	1·750	0·433	0·059			
	Untreated-healthy	..	..	0·982	0·465	0·088			
	Urea	..	..	1·623	0·512	..			
	Ca $(H_2PO_4)_2$	..	..	1·585	0·585	..			
	Ca SO_4	..	..	0·755	0·425	0·122			
	Ca Cl_2	..	..	1·821	0·556	..			
	Ca $(NO_3)_2$	..	..	1·686	0·523	..			
17th December	Untreated-chlorotic	0·866	0·240	0·966	0·310	0·053	1·444	0·666	0·095
	Untreated-healthy	0·581	0·215	0·465	0·286	0·106	1·013	0·658	0·108
	Urea	0·726	0·185	0·728	0·295	..	1·398	0·694	..
	Ca $(H_2PO_4)_2$	0·740	0·250	0·896	0·290	..	1·468	0·734	..
	Ca SO_4	0·544	0·185	0·394	0·285	0·118	0·936	0·643	0·114
	Ca Cl_2	0·908	0·258	0·952	0·270	..	1·448	0·681	..
	Ca $(NO_3)_2$	0·782	0·220	0·896	0·330	..	1·342	0·643	..
8th January	Untreated-chlorotic	..	..	0·938	0·239	0·062	1·538	0·638	0·096
	Untreated-healthy	..	..	0·422	0·242	0·110	1·010	0·625	0·118
	Urea	..	..	0·644	0·235	..	1·384	0·661	..
	Ca $(H_2PO_4)_2$	..	..	0·812	0·229	..	1·440	0·643	..
	Ca SO_4	..	..	0·392	0·230	0·120	1·006	0·656	0·126
	Ca Cl_2	..	..	0·910	0·233	..	1·496	0·661	..
	Ca $(NO_3)_2$	..	..	0·884	0·235	..	1·468	0·694	..

The data of Table V show that there is no consistent difference between differently treated samples in regard to the phosphoric acid content of the root, straw and grain whereas there is wide variation in the percentages of nitrogen and sulphur. The sulphur content of the untreated chlorotic plants is very low compared to that of the healthy plants which remains high throughout. Treatment with

psum permitted the plant to absorb sulphate ely and maintain a high concentration of this trient until maturity. These differences in sul- ur content constitute convincing proof that the lorotic plants were really suffering from sulphur ficiency. Further confirmation was obtained by sting the juices of the chlorotic, healthy and psum treated plants with benzidine hydrochloride. ystals of benzidine sulphate readily developed om the juices of the two latter plants whereas e juice of the chlorotic plants did not respond to is test.

As indicated in connection with Tables II and I the nitrogen content of the sulphur deficient nts is a very remarkable feature. Irrespective treatment the percentage of nitrogen in the plant very high up to the end of September. There- er the effect of treatment becomes prominent. the healthy as well as in the sulphate treated nts the nitrogen content falls very rapidly and the end of October the percentage of nitrogen these two sets of plants is about 30-40 per cent the value found at the end of September. On e other hand, the nitrogen content of the chlorotic nts suffers only a small reduction during the rresponding period. A further fall occurs in rogen content of all the three plants between e end of October and the middle of December t the relative percentages of nitrogen remain actically unchanged. These nitrogen changes are resented graphically in Fig. 1. In the absence sulphate abnormally high nitrogen percentage found not only in the straw but also in the grain. e accumulation of nitrogen is therefore a very aracteristic feature of sulphate deficiency.

The mature crop obtained in Experiment III s analysed for ash constituents to study the nges that might have occurred as a result of the rious treatments. These data are shown in ble VI.

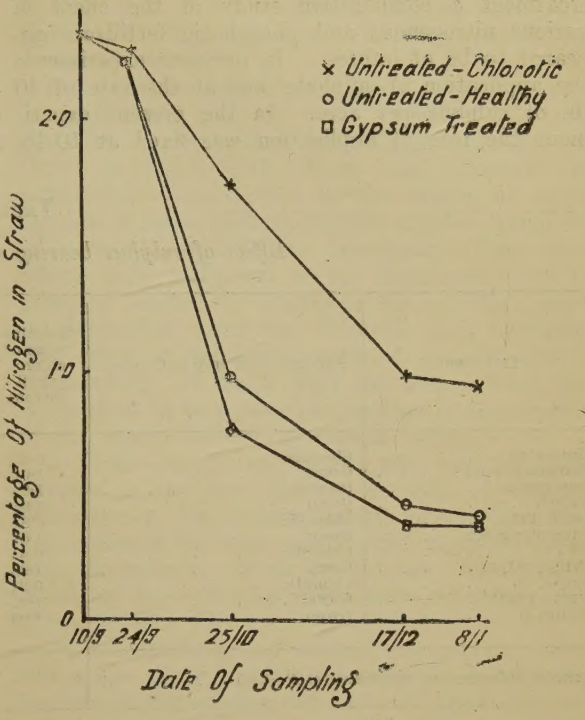


FIG. 1. The effect of gypsum on the nitrogen content of chlorotic rice plants

The figures for the major ash constituents do not show any important variation. The relatively high manganese and iron contents of the gypsum treated plants compared to the sulphur deficient chlorotic plants appear to be suggestive.

Experiment IV. This experiment was carried out during the season 1940-41 in the south-east corner of the Farm area, west of the water course. In view of the striking response of rice to sulphate

TABLE VI

Composition of mature rice plants treated with various chemicals

Treatment	Appearance of crop in October	Composition of mature straw obtained in Expt. III (percentages on dry matter)							
		N	S	P_2O_5	K_2O	CaO	MgO	Mn	Fe_2O_3
reated . .	Chlorotic . . .	0·938	0·062	0·24	1·27	0·43	0·36	0·026	0·238
reated . .	Green	0·422	0·110	0·24	1·26	0·44	0·33	0·045	0·271
a . . .	Chlorotic . . .	0·644	..	0·24	1·31	0·46	0·37	0·039	0·238
$H_2PO_4)_2$ . .	Chlorotic . . .	0·812	..	0·23	1·45	0·43	0·43	0·029	0·207
SO_4 . . .	Green	0·392	0·120	0·23	1·35	0·46	0·34	0·055	0·271
Cl_2 . . .	Chlorotic . . .	0·910	..	0·23	1·42	0·43	0·33	0·025	0·221
$NO_3)_2$ . .	Chlorotic . . .	0·884	..	0·23	1·38	0·44	0·34	0·025	0·219

treatment a comparative study of the effect of various nitrogenous and phosphatic fertilizers appeared to be of interest. In previous experiments the application of sulphate was at the rate of 40 lb. of sulphur per acre. In the present experiment the rate of application was fixed at 10 lb. of sulphur per acre as the absence of residual effect suggested that higher rates were merely wasted. The various treatments were arranged in randomized blocks with five replications. The corresponding yields and composition of the crop are shown in Table VII.

TABLE VII

Effect of sulphur bearing and other fertilizers on rice

Treatment	Appearance of crop in October	Relative value of chloro-phyll content	Mean yield per plot of 180 sq. ft. (lb.)		Percentage N in crop (oven dry basis)		Percentage S in crop (oven dry basis)	
			Straw	Grain	Straw	Grain	Straw	Grain
Untreated	Chlorotic	0·85	6·0	4·6	0·82	1·32	0·057	0·084
Sulphur powder	Green	1·00	13·5	11·6	0·37	0·97	0·127	0·125
Iron pyrites	Green	1·05	13·1	11·3	0·39	0·98	0·129	0·129
Ca SO_4	Green	1·06	12·6	10·2	0·38	0·95	0·138	0·135
Ca $(H_2PO_4)_2$	Chlorotic	0·86	7·2	5·8	0·78	1·26	0·049	0·080
Superphosphate	Green	1·01	12·0	9·9	0·40	1·01	0·124	0·115
NH_4 Cl	Chlorotic	0·88	6·8	5·2	0·85	1·21	0·061	0·081
$(NH_4)_2$ SO_4	Green	1·03	11·2	9·5	0·42	0·97	0·133	0·124
Urea	Chlorotic	0·91	7·5	6·2	0·77	1·28	0·059	0·088
Urea + $CaSO_4$	Green	1·05	12·4	10·2	0·41	0·96	0·118	0·119
Nicifos II	Green	1·03	12·5	9·9	0·38	0·98	0·125	0·129
Critical difference for significance at $P=0·05$			3·76	2·55				

Once again, the outstanding effect of sulphate is brought out by the data of Table VII. The high yields of the sulphur treated plots are invariably accompanied by low nitrogen contents and high percentages of sulphur in the crop. In the absence of sulphur the yields are consistently low with abnormally high percentages of nitrogen and low percentages of sulphur in the crop. The inverse relation between the sulphur and nitrogen contents and between yield and nitrogen content is shown in Figs. 2 and 3 respectively. It is generally believed that plants well supplied with nitrogen have a deep green colour. From the data of Table VII it is

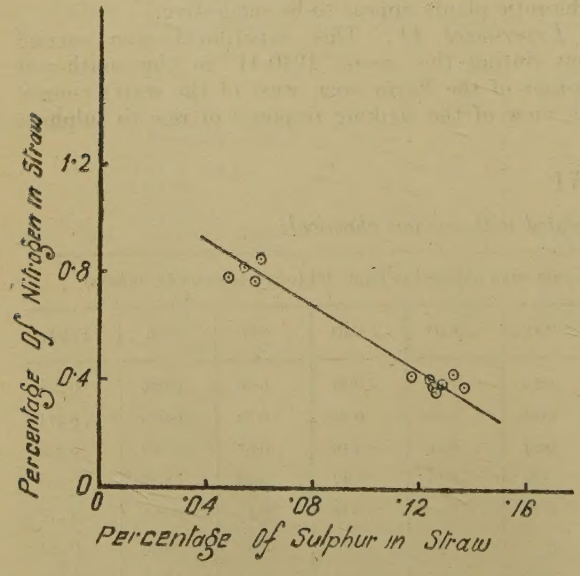


FIG. 2. The relation between sulphur and nitrogen contents of sulphur deficient rice plants

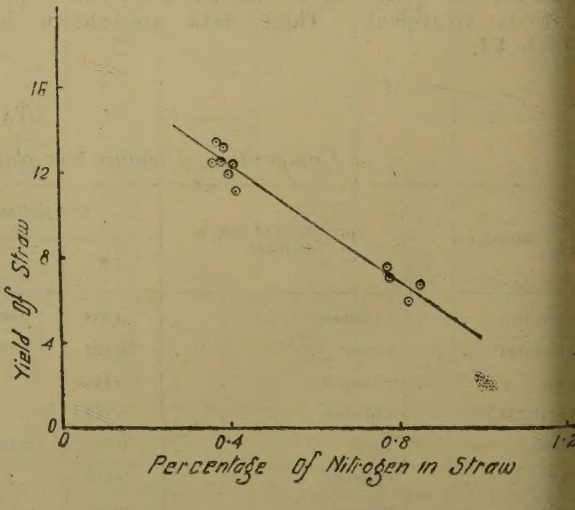
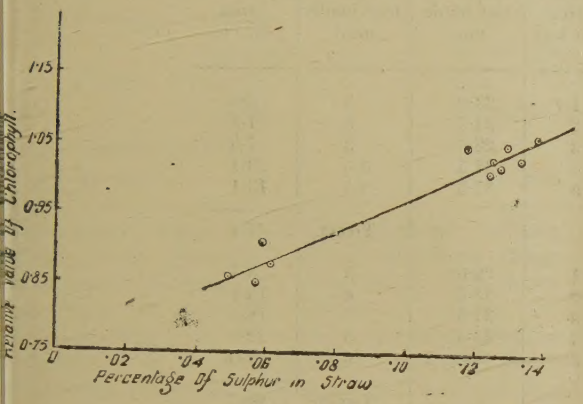


FIG. 3. The relation between nitrogen content and yield of rice under sulphur deficiency

ar that this belief is not well founded. In the esent case the chlorophyll content is proportional the sulphur content of the crop as shown in g. 4.



. 4. The relation between sulphur and chlorophyll contents of sulphur deficient rice plants

Since the plant can assimilate sulphur only when is present in the form of sulphate, there was some ubt as to whether elemental sulphur would be effective as gypsum or other sulphates. In order examine this point powdered sulphur was added the soil after temporarily draining off the water m the field and also directly to the standing er in the field. In both cases the plants re- ered showing that sulphate was produced from ted sulphur. The 'dry' application showed effect in four days while the 'wet' application k about seven days to be effective. Owing to greater convenience the 'wet' application is be preferred to the 'dry' method as there is difference in yield between these two methods application. The data in Table VII for sulphur atment are those for the wet method.

iron pyrites was also tested as a source of sulphur. r this purpose iron pyrites has the advantage t unlike sulphur it occurs in many parts of Burma l is very cheap. Moreover, since sulphur is an redient of certain common explosives, restric- ns may sometimes be placed on its open sale. art from these reasons, iron pyrites is even more dily oxidized than sulphur when applied to the e field.

From Experiment IV it may be concluded that effectiveness of nitrogenous and phosphatic tilizers is not exclusively due to the nitrogen or osphoric acid contained in them and that sul- ate plays a very important role in the manuring rice. From this standpoint ammonium sulphate uld be regarded as superior to ammonium chloride, a and cyanamide, and superphosphate as superior to bonemeal, rock phosphate, calcium metaphosphate and other phosphatic fertilizers which are devoid of sulphur.

Plant measurements and other observations were recorded from time to time. Some of the data obtained in connection with Experiment IV are shown in Table VIII. These data illustrate the remarkable improvement in the height of plant, the size of leaves and the number of tillers produced as a result of sulphate treatment. That these effects were really due to the treatment could be accepted because the treatment was actually applied in September after the chlorosis had appeared. The effect of sulphate treatment on leaf area is outstanding. In Table VIII the area of each leaf is assumed to be a constant fraction of the product of its length and its maximum width.

In order to get an insight into the metabolic changes in the rice plant as a result of sulphate deficiency a few determinations of nitrogen and carbohydrate fractions were made on plants taken from Experiment IV on 10 October. These data, which are however of a preliminary character, are shown in Table IX.

The accumulation of soluble and total nitrogen and a low sugar content appear to be noteworthy features of the sulphur deficient rice plant.

Sulphur deficiency symptoms in plants in nutrient solution. An experiment was carried out by the use of nutrient solutions to produce the symptoms of sulphur deficiency for further confirmation of the observations made on field samples. Seedlings were raised in wet sand and after a fortnight's growth they were transferred to the appropriate culture solutions.

The symptoms of sulphur deficiency developed gradually and were characteristic at the end of four weeks after transfer of the seedlings to the culture solution which contained low amount of sulphate or from which sulphate had been omitted. The following symptoms could be distinguished (Plate XIII, fig. 2):

(*a*) The tops were stunted and showed a tendency to be fanshaped.

(*b*) The leaves became yellowish green in the initial stages of the deficiency. The relative chlorophyll contents are shown in Table X.

(*c*) The leaf blades of the sulphur deficient plants were short and narrow compared to those of plants growing in complete culture solution with full strength of sulphate.

(*d*) Tillering and other growth characters were reduced corresponding to the degree of sulphur deficiency suffered by the plant.

(*e*) The roots of plants growing in sulphur deficient solution were of a pure white colour and extraordinarily long. Secondary roots were completely absent.

TABLE VIII

Morphological features of sulphate treated and untreated rice plants (measurements made on 15 October)

Treatment	Average height of plant cm.	Average number of tillers per plant	Blade No. counting from oldest leaf	Average length of leaf blade cm.	Maximum width of leaf blade mm.	Index of leaf area sq. cm.
Untreated-chlorotic	61	3·3	1	23·0	3	6·9
			2	24·5	3	7·3
			3	23·5	3	7·0
			4	37·5	3·5	13·1
			5	37·5	3·5	13·1
					TOTAL	47·4
Untreated-revived	76	4·6	1	29·0	3	8·7
			2	33·5	4	13·4
			3	37·5	5	18·8
			4	45·5	5	22·8
			5	45·0	6	27·0
					TOTAL	90·7
Untreated-healthy	101	6	1	32·5	3	10·8
			2	40·5	5	20·3
			3	49·0	6·5	31·9
			4	58·0	7·5	43·5
					TOTAL	106·5
Gypsum	120	6	1	46·0	5	23·0
			2	53·0	6	31·8
			3	58·0	7	40·6
			4	58·5	7	41·0
			5	62·0	8	49·6
			6	53·0	8·5	45·0
					TOTAL	231·0
Sulphur	130	5·3	1	49·0	7	34·3
			2	60·0	8	48·0
			3	66·0	8·5	56·1
			4	60·0	10	60·0
					TOTAL	198·4

TABLE IX

Nitrogen and carbohydrate fractions in untreated and sulphate treated rice plants (sampled on 10 October, 1937)

Treatment	Nitrogen fractions (percentage of N on dry matter)			Carbohydrate fractions (percentage of hexoses on dry matter)		Percentage of S on dry matter
	Soluble N	Protein N	Total N	Soluble sugars	Starch and dextrin	
Untreated-chlorotic	0·454	1·227	1·681	4·20	1·44	0·063
Untreated-healthy	0·127	0·847	0·974	8·13	1·77	0·094
Gypsum treated	0·093	0·665	0·758	9·15	1·68	0·118

TABLE X

Characteristics of rice plants grown in culture solutions

Test	Composition of culture solution	Appearance and relative value of chlorophyll	No. of tillers	Height of plant (cm.)	Length of largest leaf-blade (cm.)	Maximum width of largest leaf-blade (mm.)	Length of root (cm.)
	Complete—full sulphate	Green 1·0	11	80	52	10	18
	,, 1/10 sulphate	Chlorotic 0·96	8	55	28	6	27·5
	Complete—full sulphate	Green 1·0	9	76	49	12	18
	,, 1/10 sulphate	Chlorotic 0·93	5·6	48	24·3	6	37
	Complete—full sulphate	Green 1·0	13	75	51	9	26
	No sulphate	Chlorotic 0·55	1·5	33·4	17	4	56·3

Rice plants grown in sulphur deficient culture lutions were generally similar to those taken om sulphur deficient plots in the field. In samples ken from the field the symptoms were not so ute as in those grown in solutions probably because e deficiency in the field was not extreme. There as another important difference between the two ts of plants. The chlorotic plants found in the ld became deep green at a later stage whereas is effect was not seen in solution culture.

Sulphur content of Burma soils. Since sulphur assimilated by plants only when present in the rm of sulphate, the actual sulphate content of e soil is the proper basis for assessing the available lphur content of a soil.

Conventional soil analysis by extraction with ncentrated hydrochloric acid generally includes e SO_3 content. Taking into account the many fficulties involved in determining small amounts sulphate in the soil extract the available figures serve only for qualitative purposes. These ures probably include most of the sulphate and rt of the organic sulphur present in the soil. e true sulphate content and the total sulphur ntent of representative soils determined by methods scribed under 'Methods and materials' are shown Table XI.

TABLE XI

Sulphur contents of some Burma rice soils

erial No.	Location of soil	Total sulphur as parts per million of S	Water soluble sulphate as parts per million of S	Percentage of N in soil	Percentage of organic carbon in soil
1	Mandalay	130	7·4	0·05	0·42
2	Kywezin	100	10·0	0·04	0·36
3	Chiba	300	12·0	0·04	0·25
4	Ye-u	300	4·8	0·04	0·33
5	Tabayin	100	6·0	0·05	0·41
6	Ngeyoktun	20	1·0	0·03	0·25
7	Hmawza	500	64·0	0·03	0·32
8	Hmawbi	800	64·0	0·07	0·56
9	Myaungmya	1,200	150·0	0·17	2·23
10	Mudon	1,400	220·0	0·08	1·11
11	Yedashe	800	50·0	0·08	0·81

Of the soils listed in Table XI the first six strongly responded to sulphate manuring while the other five did not. This result is in close agreement with the soluble sulphate content of these soils which appear to be sharply contrasted in this respect.

DISCUSSION

(a) *Morphological features.* Sulphur deficiency caused characteristic symptoms in the rice plant. The pale yellowish green colour, the reduction in height and leaf area, the extraordinary elongation of the roots with suppression of secondary roots, and other features found in the rice plant are similar to those observed in various other plants.

The pale yellowish green colour induced by sulphur deficiency has been observed in corn [Duley, 1916], in alfalfa [Reimer and Tartar, 1919; Olson and St. John, 1921], in tomato [Nightingale *et al.*, 1932], in tea [Storey and Leach, 1932], in sugarcane [Martin, 1934], in soybean [Eaton, 1935], in tobacco [McMurtrey, 1938], and in citrus [Chapman and Brown, 1941]. That the chlorosis is more prominent in the younger leaves was noted by McMurtrey, Eaton, Chapman and Brown, and others. The recovery of the green colour by the affected leaves was observed by Chapman and Brown in citrus. Manuring with sulphates was found to produce a deep green colour in the leaves of corn [Duley, 1916], in alfalfa [Reimer and Tartar, 1919], and in beets [Demolon, 1912].

Deuber [1926] determined the chlorophyll content of soybean plants grown in culture solutions and found that it increased with increasing concentration of sulphate within certain limits. Since sulphur is not present in the chlorophyll molecule, the manner in which sulphur deficiency causes chlorosis is not understood. Maze's test [1911] with sodium sulphate gave a green spot on the chlorotic leaves of rice suffering from sulphur deficiency. On the other hand, Buslova [1941] has observed that when sulphur deficiency is accompanied by nitrogen deficiency the spot test for sulphur is negative unless nitrogen is also supplied. She noted however

that the spot test with ammonium nitrate gives a green spot in cases of nitrogen deficiency whether accompanied by other deficiencies or not. It may thus be concluded that the effect of sulphur is exercised indirectly through its influence on nitrogen metabolism.

The reduction in height observed in the sulphur deficient rice plant does not appear to be a general feature of other crops suffering from the same deficiency. Thus stem elongation was found to be a peculiar characteristic in tomato [Nightingale *et al.*, 1932] and in soybean [Eaton, 1935] when subjected to sulphur deficiency.

The reduction in leaf area observed in sulphur deficient rice appears to have been known for a long time in other affected crops. Duley [1916] observed this effect in corn, and Eaton [1935] in soybean, sunflower and other plants.

Sulphur deficiency causes a great reduction in the yield of the rice crop. The lowering of yield of the vegetative portion in tomato, soybean, sunflower and certain other crops appears to be caused by reduction in the thickness of the stems and in the size of the leaves. Although the stems of sulphur deficient rice plants were somewhat thinner than those of normal plants the reduction in yield must be attributed to reduction in height, reduction in leaf area, and, most of all, to the reduction in the number of tillers. It is generally assumed that tillering in cereals is controlled by nitrogen and phosphate. The data obtained in the present work show that tillering of rice is reduced by sulphate deficiency. The significance of sulphate in rice fertilization is thus again demonstrated.

The efficiency of sulphate as a nutrient appears to be very high as Mitscherlich's 'Wirkungsfaktor' for sulphur is C=15·0 compared to P_2O_5 for which C=0·5 [Scheffer, 1938]. Hence the response of a crop to a small dose of sulphate may be expected to be high while the effect of a deficiency will be severe. On the whole, both these effects have been found to hold good in the case of the rice plant.

Root weight is not appreciably reduced in many plants by sulphur deficiency [Eaton, 1935]. Nightingale *et al.* [1932] however found that the roots of sulphur deficient tomato plants were of small diameter and were similar to those of nitrogen deficient plants. Martin [1934] has stated that sulphur-deficient sugarcane plants developed a poor root system. In the rice plant the effect of sulphur deficiency on the root system is characteristic. There is an extraordinary elongation of the primary roots with complete suppression of the secondary roots. The whole root system is of a white colour. Although a well developed root system is an index of healthy growth and high yield it is practically certain that there is no close relation between yield and size of root system. In the case of the rice plant a well branched root system seems to be more important than its size or weight. In manurial experiments with ammonium sulphate Espino [1934] found that the fertilized rice plants 'produced more but shorter roots than the unfertilized plants' and that with a heavy dose of ammonium sulphate 'the plants produced large tops and strikingly small root systems'. Libatique [1930] observed that with increased application of ammonium sulphate to rice a corresponding increase was obtained in yield of tops and in the chlorophyll content of the leaves. He has reported that this condition is always accompanied by a poor root development.

The appearance of sulphur-deficient plants is stated to be similar to that of nitrogen-deficient plants [Kraus and Kraybill, 1918]. The pale yellowish green colour and the small size of leaves and stems are similar in both types of rice plants. The data obtained in a solution culture experiment on the effects of certain deficiencies on the rice plant are shown in Table XII. Secondary roots were absent in all the deficiencies.

Of the major nutrients, a deficiency of nitrogen, phosphorus, potassium, or magnesium first affects the older leaves which suffer rapid senescence but colour symptoms and other features serve to differen-

TABLE XII

Effect of certain deficiencies on the rice plant

Nature of culture solution	Tillers	Tops			Roots	
		Average height in cm.	Colour	Relative chlorophyll content	Average length in cm.	Colour
Complete	12	74	Green	1·00	30	Greyish white
Minus N	0	28	Yellowish green	0·96	36	Greyish white
Minus P	0	48	Dark green	1·15	41	Deep brown
Minus S	1·5	39	Yellowish green	0·65	53	White

te between their effect. On the other hand. leficiency of sulphur or calcium first affects the unger leaves of rice which show chlorosis and ier symptoms. It has also been ascertained at a deficiency of the minor elements manganese, n or boron affects the younger leaves of rice. ry similar effects have been reported in the case tobacco [McMurtrey, 1938].

(b) *The effects of sulphur deficiency on the composition of the rice plant.* Blankenburg [1933] states at rice straw contains 0·356 per cent of SO_4 which rresponds to 0·119 per cent of sulphur. According Gile and Carrero [1915] the sulphur content the mature tops (straw and grain) of upland rice 0·16 per cent. Hart and Peterson [1911] found at rice grain contained 0·126 per cent of sulphur. comparison of the sulphur content of rice with at of other cereals is interesting. The following ta (Table XIII) are taken from Hart and Peterson's rk.

TABLE XIII

Sulphur content of some cereals

Cereal	Percentage of sulphur in		Remarks
	Grain	Straw	
. .	0·189	0·195	Hart and Peterson
. .	0·170	0·160	,,
. .	0·153	0·147	,,
. .	0·139	0·126	,,
. .	0·126	...	,,
. .	0·125	0·128	From Table VII

thus appears that rice has the lowest sulphur ntent among the important cereals and that the lphur content of the grain of each cereal is approximately equal to that of the corresponding raw.

From Tables V and VII it will be seen that the rmal rice plants contain approximately the same rcentages of sulphur in the straw and grain and at these figures agree with the published values und by other workers. According to the data esented in Tables II, VI and VII it is clear that hen there is a deficiency of sulphur there is a eat reduction in the sulphur content of the raw but that the grain suffers only a moderate duction. This behaviour is analogous to that und in phosphate deficiency.

Since all plant proteins contain nitrogen and lphur, the relationship between these elements of great importance in the nutrition of the plant. the case of the rice plant it has been found that lphur deficiency does not influence the P_2O_5 ntent of the plant (Tables II and VI), but causes remarkable accumulation of nitrogen in the plant (Tables II, VI and VII), apparently due to the poor growth of the sulphur deficient plant. Protein nitrogen as well as soluble nitrogen showed this increase. Nitrogen accumulation, particularly in soluble forms, has been observed in several other crops. Thus Eaton [1935] found that the stems of soybean plants subjected to sulphur deficiency contained much higher amounts of all forms of nitrogen compared to plants receiving a complete nutrient. Nitrogen accumulation due to sulphur deficiency has been found in tomato [Nightingale *et al.*, 1932], in sunflower [Eaton, 1941], in black mustard [Eaton, 1942], and in citrus [Chapman and Brown, 1941]. On the other hand, Greaves and Bracken [1937] found a highly significant positive correlation between the total sulphur and the total nitrogen contents of wheat grain from 21 varieties. Moreover, it has been established that sulphate manuring not only improved the colour of the plant but also increased the nitrogen content of legumes such as alfalfa [Reimer and Tartar, 1919] and clover [Miller, 1919]. This beneficial action has been attributed to the increased development of nodule organisms and better root development.

Various suggestions have been offered to account for the accumulation of soluble nitrogen in plants in cases of sulphur deficiency. According to Nightingale *et al.* [1932] and Eaton [1935] a lowered activity of the enzyme reductase would account for the presence of increased amounts of nitrate and proteolysis of part of the built-up protein would account for the presence of large amounts of partially metabolized nitrogen in the plant. Wood and Barrien [1939] have advanced the view that a stable sulphur-rich protein and an unstable sulphur-deficient protein might be formed in cases of sulphur deficiency. Wood [1941] has summarized the present state of knowledge of sulphur metabolism in plants and has suggested an 'energy' hypothesis as an alternative mechanism for the reduction of sulphate and the building up of protein and other organic nitrogen compounds. The existence of proteolysis is, however, generally accepted. In rice plants grown under moderate to acute deficiency the primary formation and accumulation of protein from the available sulphur received confirmation from the low percentage of soluble sugars formed in the sulphur-deficient plants. The carbohydrate data for normal plants (Table IX) agree with those found by Dastur and Pirzada [1933]. The recovery of the green colour by the plant at a later stage indicates the development of chlorophyll, rendered possible by some modification in nitrogen metabolism. The metabolism has not been sufficiently studied to warrant further discussion.

(c) *Sulphates as fertilizers.* Gypsum has been in use as a soil amendment since Roman times [Collings, 1941] though its function had not been

determined. The chief functions of gypsum recognized in recent years are the correction of soil alkalinity and the displacement of available potassium for crops. Occasionally gypsum had been regarded as a source of calcium but rarely as a source of sulphur. Crocker [1922] has summarized the history of gypsum as a fertilizer. Greaves and Carter [1919] investigated the use of gypsum and concluded that 'it is the most powerful soil stimulant that we have'. Katayama [1905] compared the effect of calcium carbonate and calcium sulphate on rice grown in sand culture. The plants grown with calcium sulphate had a deep green colour and gave a greater yield than plants grown with calcium carbonate which were chlorotic. Greaves and Carter [1919] as well as Olson and St. John [1921] accept the result as proof of the beneficial effect of sulphur as a nutrient for rice. Katayama, however, attributed the difference in behaviour to the depression of the availability of phosphoric acid of bone dust by calcium carbonate. In fact Katayama had added to both sets of pots substantial amounts of ammonium sulphate, potassium sulphate, and ferrous sulphate as nutrients while bone dust was used as the source of phosphoric acid. The chlorosis and reduced yield obtained in the case of calcium carbonate could have been caused by the precipitation of all the soluble iron from the medium. Although magnesium carbonate was present in all the pots of both series it could not have exerted a depressing action owing to the fact that it was applied in the form of magnesite which is of low reactivity. Ghosh and Basu [1925] obtained increased yields of *Phaseolus mungo* in South Bihar by the use of gypsum and certain other sulphates. They pointed out however that the chlorotic condition of the plants was not controlled by the sulphates. It is therefore doubtful whether this is a case of sulphur deficiency.

The development of microbiological studies in connection with the oxidation of sulphur in soil led to the use of sulphur in the reclamation of alkali soils [Waksman *et al.*, 1923]. Demolon [1912, 1913] revived the observation of Mares [1869] that when added to the soil sulphur was oxidized to sulphuric acid, and thereby became available to crops as a source of sulphur. Duley [1916] found that sulphur was oxidized to sulphate in quartz sand thereby showing that oxidation can occur in the absence of soil. Vermorel and Danthony [1913, 1914] used iron pyrites as a source of sulphur for crops. Kappen and Quensell [1915] studied the sulphur cycle in soil and found that all forms of sulphur are ultimately converted into sulphate.

Lipman and Gericke [1918] found that ammonium sulphate was superior to other forms of ammonium fertilizers in a sandy soil. Reimer and Tartar [1919] have stated that superphosphate may serve as a source of sulphur for crops. Potassium sulphate, sodium sulphate, ferrous sulphate, and other sulphates have also been found to benefit crops as sources of sulphur [Dymond *et al.*, 1905; Lipman *et al.*, 1912]. Shedd [1913] suggested that sulphur should be placed with N, P and K as a limiting factor in crop production.

The data given in Table VII prove that in cases of sulphur deficiency it is possible to obtain large increases in yield of rice by the use of calcium sulphate, sulphur, iron pyrite, ammonium sulphate, or superphosphate. In occasional tests sulphuric acid, sodium sulphate and magnesium sulphate have proved satisfactory sources of sulphur for rice. It is remarkable that none of these treatments showed any residual effect as chlorotic symptoms again appeared in the same patches which had received sulphur manuring in the previous year. The sulphur might have been lost as mercaptans or H_2S or assimilated by micro-organisms into stable organic forms but the exact cause has not been determined.

The results presented in Table VII point to the great importance of sulphur in the manuring of rice. In the selection of fertilizers for rice areas it will be a wise policy to include some sulphate in the material used. The outstanding effect of ammonium sulphate in the manuring of rice is too well known to require further advocacy. It is believed that deficiency of nitrogen is the most outstanding cause limiting yields of crops in India. Out of the more important nitrogen fertilizers such as calcium cyanamide, urea, ammonium chloride, ammonium nitrate, calcium nitrate, sodium nitrate, and ammonium sulphate, sulphur is present only in the last compound. When nitrogen is the only nutrient to be added in rice growing it is desirable to employ ammonium sulphate in spite of its relatively low nitrogen content and the poor sulphur resources of India, which may be used as arguments against its manufacture in India. It is not, however, suggested that the whole of the nitrogen for rice should be in the form of ammonium sulphate. When superphosphate is being applied in addition to nitrogen, the latter may be entirely in the form of urea or ammonium chloride. On the other hand, if only nitrogen is required it may still be possible to effect economies by using a mixture of urea and calcium sulphate or a mixture of ammonium sulphate and ammonium chloride.

Gericke's [1930] claim that rice can make satisfactory growth if the seedlings had received sulphate for six weeks initially probably applies only to water culture. It has been found that under field conditions fully manured seedlings do not make satisfactory growth when transplanted into sulphur-deficient soil.

t has frequently been asserted that organic nures can take care of all the requirements of plant and that farmyard manure would serve purpose very satisfactorily. From actual tests Mandalay it was found that farmyard manure lied at the rate of 10 tons per acre failed to ply sulphur to the rice crop in soil causing sulphur ciency. Analysis showed that the manure con- ned 0·08 per cent sulphur which corresponds to ut 1·8 lb. per ton or an application of 18 of sulphur per acre. Green manure on the er hand was fairly satisfactory, probably owing the presence of soluble sulphate in the material the ready decomposition of the proteins liberat- sulphur.

d) *Soil as a source of sulphur for crops.* The phur content of soils is quite small and is generally ch lower than the phosphoric acid content. It a noteworthy fact that nitrogen, phosphorus sulphur, three of the most important major rients, are present in very limited amounts in ls. According to Berthelot and Andre [1892] sulphur content of soil is made up of organic phur compounds and inorganic sulphate. To se forms may be added sulphides which are ely to be present in appreciable amounts under e field conditions. The bulk of the sulphur is, wever, in organic form and as might be expected re is a good correlation between the nitrogen and phur contents with the organic matter of the is (Fig. 5).

The sulphur content of a soil is derived from rious sources : (i) from the sulphide content of parent material, (ii) from the sulphur contained rainfall and irrigation water, (iii) from smoke and ste gases in industrial areas, (iv) from organic nures, and (v) from sulphate fertilizers added casionally. Under conditions in India and Burma ganic manures are the only important sources ntributing to maintain the sulphur content of e soil. The irrigation water used at Mandalay s almost entirely free from sulphates. Among ctors which deplete the sulphur content of the il the most important ones are the loss in drainage d run-off and the loss by crop removal. The ss of sulphur in drainage at Rothamsted has been timated at 20 to 80 lb. per acre per annum [Stewart, 20]. There is no information on the amount of lphur lost in drainage in India or Burma. On e basis of an average total acre yield of 4,000 . of rice grain and straw the loss of sulphur om the soil is about 10 lb. per annum per re. Another mode of loss of sulphur from rice lds may also be recognized. In waterlogged il sulphate undergoes total reduction to H_2S or The H_2S reacts with the iron compounds in e soil forming FeS. This reaction is practically dependent of *p*H and does not require the presence of iron in soluble form. Part of the H_2S however escapes in solution [Mann and Tamhane, 1910;

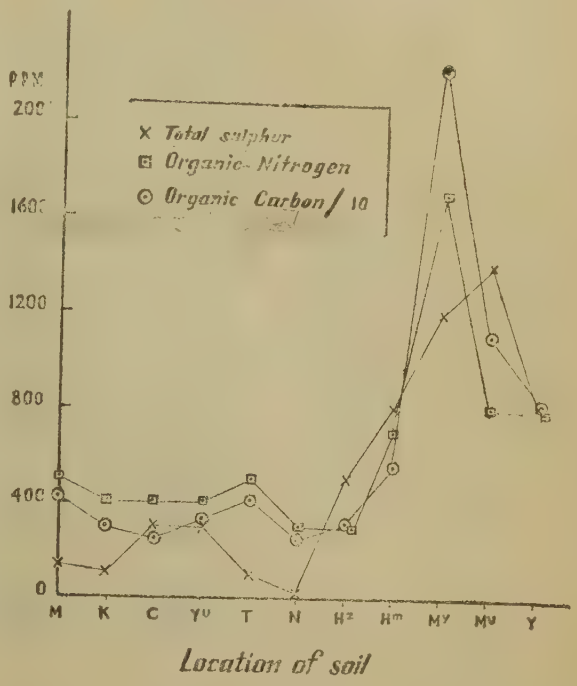


FIG. 5. The sulphur, nitrogen and organic carbon content of some Burma rice soils

Howard, 1925]. Bertrand and Silberstein [1928 1932] have drawn attention to the possibility that the barium content of soils may reduce the soluble sulphate content of soils to low levels.

The rice plant like other green plants can apparently utilize sulphur only when present in the form of sulphate. Organic and other forms of sulphur are not useful until they are transformed into sulphate. The total sulphur content of a soil cannot serve as a reliable index of available sulphur as the conversion of humic sulphur into sulphate has been shown to be extremely slow [Rippel, 1928]. Lysimeter studies [McIntire *et al.*, 1917; Lyon and Bizzell, 1918] have shown that sulphates are readily lost from soil in drainage water and have led to the general assumption that the soil sulphur undergoes continuous oxidation to sulphate and becomes easily available to crops. Owing to the reducing conditions under which the rice crop is cultivated the availability of sulphur must always remain a limiting factor in obtaining high yields. Since normal growth however takes place under the ordinary conditions of rice cultivation there must be some mechanism for the continued supply of sulphate to rice.

Since the formation of H_2S and FeS under waterlogged conditions appears to be well established,

the most reasonable explanation for the formation of sulphate would be through the oxidation of FeS to $FeSO_4$. Actual test revealed the fact that a normal soil soon blackened on waterlogging and in the course of a few days ferric hydroxide was formed which remained in greatest concentration near the surface of the water layer. The following mechanism appears probable. Ferrous sulphide formed in the soil layer undergoes oxidation to ferrous sulphate by the action of the oxygen dissolved in the water layer. The ferrous sulphate reaches the water surface where a higher oxygen tension causes further oxidation and precipitation of ferric hydroxide leaving the sulphate in solution combined with bases. On the other hand, there was very little blackening or precipitation of ferric hydroxide in a soil causing sulphur deficiency in the rice crop. Both soils contained approximately equal percentages of organic carbon and total sulphur so that the difference in behaviour might be due to a difference in the nature of the microflora or due to a difference in stability of the organic sulphur compounds present in these soils.

Summary

1. Sulphur deficiency in the rice plant was characterized by (*a*) chlorosis, (*b*) reduction in height, leaf area, and tillering, (*c*) failure to reach maturity, and (*d*) great reduction in yield of crop.

2. By a series of experiments it was shown that the symptoms of sulphur deficiency could be corrected by sulphur treatment of the soil.

3. The sulphur content of the affected plants was found to be abnormally low but on treatment with sulphur the plants absorbed the nutrient readily.

4. The most characteristic abnormality in the composition of the plant was in its nitrogen content. Sulphur deficiency was always accompanied by an enormous accumulation of nitrogen in straw and grain. The presence of a high percentage of soluble nitrogen in the vegetative portion was a noteworthy feature. On manuring with sulphur the nitrogen content became normal.

5. The ash composition was not affected appreciably by sulphur deficiency, though the iron and the manganese contents tended to be low.

6. As sources of sulphur, it was found that elemental sulphur, iron pyrites, gypsum, magnesium sulphate and other sulphates, as well as the nitrogenous and phosphatic fertilizers containing sulphur were equally satisfactory. Application at the rate of 10 lb. of sulphur per acre was sufficient to produce the maximum effect. Manuring with sulphates did not produce any residual effect. Farm-yard manure failed to supply available sulphur to the rice crop.

7. The symptoms of sulphur deficiency observed in the field were confirmed by experiments with nutrient solutions. Acute deficiency of sulphate led to an extraordinary elongation of the root system whic was pure white and completely devoid of secondar roots.

8. The study of the sulphur content of some Burm soils showed that response to manuring was highl correlated with soluble sulphate content.

9. The results obtained in the present investiga tion have been discussed in relation to sulphu deficiency in other crops.

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A B A B

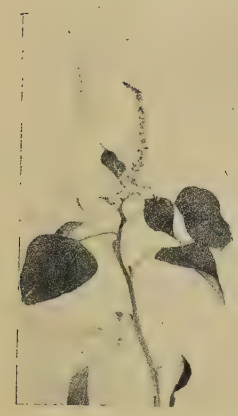
FIG. 1.

A. Complete nutrient solution; B. Sulphur deficient solution. 1 and 2. Healthy plants; 3 and 4. Chlorotic plants. Field samples transferred to culture solutions on 10 September. Photo: 16 December

FIG. 2.

Effects of sulphur deficiency on rice plants. (Development in culture solutions). Transplanted : 26–7–41. Photo : 10-9-41

Complete No SO4



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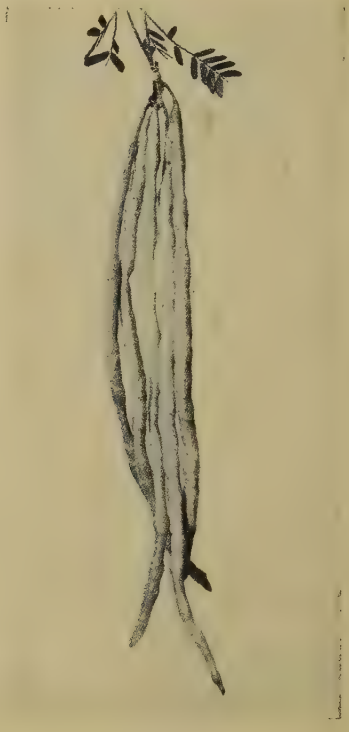

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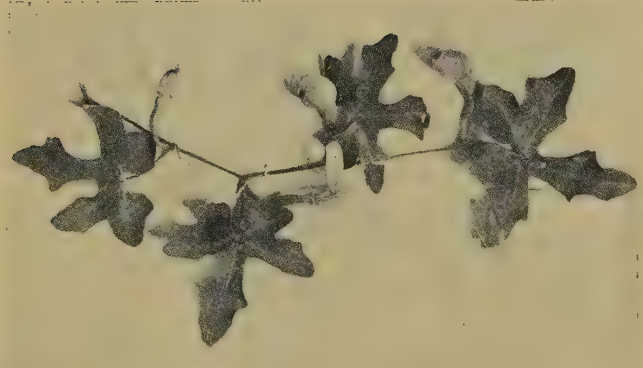

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8

Wild edible plants

FIG. 1. *Amarantus viridus*, a leafy branch with a terminal spike-like receme.

FIG. 2. *Digera arvensis*, a leafy branch with axillary spikes.

FIG. 3. *Prosople spicigera*, a cluster of pods.

FIG. 4. *Portulaca oleracea*, a young plant.

FIG. 5. *Tribulus terrestris*, a branch before flowering.

FIG. 6. *Capparis aphylla*, unripe fruits on leafless branches.

FIG. 7. *Cephalandra indica*, a branch with flowers and young fruits.

FIG. 8. *Cordia myxa*, a cluster of fruits.

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SOME USEFUL WILD PLANTS OF THE DELHI PROVINCE

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(With Plates XIV-XVI and two text-figures)

dia with its wide range of soils, climate and itudes possesses a wealth of plant material which l remains to be systematically studied and loited. The present paper represents a small inning in this direction and deals with the economic nts found within the confines of province of Delhi. rief description is given of each plant, with short notes on its useful characters. This information in many cases is incomplete and much remains to be done by botanists, pharmacologists and others before we will be in a position to claim that we are making full use of our natural resources. Mention has not been made of plants useful as sources of timber, gum, resin, tannin and dye, etc., as very few such

plants were met with in a truely wild state and that too in small numbers.

Edible plants

Always of interest to the poor, wild edible plants have a greater importance to-day when we are faced with food shortage. Moreover, some of the wild fruits and edible weeds apart from being palatable, have high nutritive value and afford a change in the routine dietary of the less-moneyed classes. The value of wild fruits is often better appreciated by a tired pedestrian who happens to find along his path some trees of the wild date (*Phoenix sylvestris*), *jaman* (*Eugenia* Sp.) or mulberry (*Morus* Sp.), or a few shrubs of the wild *ber* (*Zizyphus* Spp.) laden with ripe fruits ; after tasting their fruits he feels that he can resume his journey with renewed energy. Some of the wild leafy vegetables have been found to be rich in vitamins and are tasteful when properly cooked. These plants should not be scorned simply because they happen to be growing wild. The following are the common edible wild plants of the Delhi province :

1. *Pot herbs*

Amarantus viridus L. (Amarantaceae). An erect much-branched, glabrous annual, 1-2 ft. high ; leaves 1-3 in. long, ovate, flowers green, arranged in slender axillary and terminal spike-like racemes. (Plate XIV, fig. 1). It is a common weed of the rainy and cold seasons. The tender tops and inflorescences are cooked in the manner of spinach and purslane.

Amarantus blitum L. (Amarantaceae)—vern., *chaulai*. A glabrous, procumbent annual with small long-petioled, oblong-ovate leaves ; flowers yellowish green, in axillary clusters. A common weed in moist places, flowering throughout the year. It affords several cuttings in the season. Not only the tops but the branches are also tender so that the greater portion of the plant can be used for cooking. A tall variety of this is often cultivated. All the aerial parts of the plant are edible.

Chenopodium album L. (Chenopodiaceae)—vern., *bathua*, *bathu*. An erect annual, sometimes growing high up to 10 ft. The lower leaves are rhombic-ovate, the upper ones mostly narrow, entire, generally white and mealy beneath. Flowers inconspicuous, arranged in cymose clusters forming long terminal panicles.

It is a very common winter weed of cultivated and waste places. It appears in summer also, but the summer plant is distinct from the winter plant in colour and habit of growth. Leaves and tender twigs are cooked alone or as is more common practice, mixed with young *Brassica* (*sarson*) inflorescences and gram tops. The presence of *bathua* is said to add to the flavour. This plant is very rich in potassium salts.

Digera arvensis Forsk. (Amarantaceae)—vern., *tandla*. A slender quick-growing, common annual weed of the rainy season. Plants up to 2 ft. high; leaves thin, mostly ovate, flowers pink, in axillary spikes (Plate XIV, fig. 2). The leaves and tops of the plant along with the tender inflorescences are cooked as a pot herb. It compares quite favourably with spinach.

Ipomoea reptans Poir., syn. *Convolvulus repens* Willd., (Convolvulaceae)—vern., *sarnali*. An aquatic trailig herb, common in ditches. Leaves 2-6 in. long, cordate or hastate at the base, cymes 1-5 flowered ; flowers pale rose-coloured. Flowers during winter. The young shoots are eaten as a vegetable.

Portulaca oleracea L. (Portulacaceae)—vern., *kulfa*, *salunak*. A succulent trailing annual with spathulate or linear sub-opposite leaves ; flowers yellow with fleshy sepals (Plate XIV, fig. 4). A weed of the sandy places, growing throughout the year. A variety with ascending branches and broad spathulate leaves is cultivated in gardens. It is much used as a pot herb and some people have a special liking for it on account of its acid taste.

Portulaca quadrifida L. (Portulacaceae). It can be distinguished from *P. oleracea* by the much smaller leaves and four instead of five petals. It is always prostrate with very slender branches and is more common than the preceding species. There is not much difference in the taste of either the raw or the cooked material of the two species.

Stellaria media Cyrill. (Caryophyllaceae). A very common winter weed. It grows well in moist and shady places specially in the gardens. A delicate herb with opposite ovate leaves ; flowers small, white, in terminal leafy clusters or solitary in the leaf axils. When properly prepared, it makes an excellent green vegetable of good flavour.

Tribulus terristris L. (Zygophyllaceae)—vern., *Gokhru*, *bhakhra*, *bhankhra*. A prostrate, branched annual or biennial herb, so abundant in some places that it forms a green carpet on the surface. Leaves compound with 5-7 pairs of leaflets ; flowers yellow, axillary ; cocci of the fruit spiny (Plate XIV, fig. 5). It is commonly found in sandy and rocky places and comes up with the first showers of rain. Leaves when cooked with *moth* seeds (*Phaseolus aconitifolius*) and the two together pounded into a paste form an excellent dish.

Edible fruits

(i) *Unripe fruits, cooked as vegetables*

Momordica charantia L. (Cucurbitaceae)—vern., *karela*. Two distinct wild varieties are met with in the rainy season, one near Okhla and the other on the sides of the Western Jumna Canal. Both have small roundish fruits. The fruits of the Okhla

ariety lack the characteristic bitterness and the rojections on the surface are not so pointed. The ruits of the other variety are bitter like those of the ultivated varieties.

Prosopis spicigera L. (Mimosoideae)—vern., *and, sangar.* A medium-sized evergreen, spinescent ree with creamy-white flowers in slender spikes, -5 in. long. Pods 5-10 in. long, cylindric (Plate XIV, g. 3). Flowers in April and the pods which resemble he pods of *lobia* (*Vigna catiang*) in shape and size, re available in May. These are cut into small ieces and cooked like *lobia.* The local people, owever, believe that its too frequent use causes isorders of the stomach.

Trichosanthes cucumerina L. (Cucurbitaceae)—ern., *jangli chachinda.* A slender climber seen on he roadside bushes on the Rohtak road between he villages of Shakurpur and Nangloi. Flowers hite, with fimbriated petals ; fruits small, roundish, aving white streaks, ending in a short beak. The lants bear profusely. Fruits ripen in September-October.

Trichosanthes dioica Roxb. (Cucubitaceae)—vern., *arwal, parol.* A slender, more or less scabrous limber, commonly seen on *Capparis sepiaria*, on he sides of Western Jumna Canal. Leaves dentate, lowers white ; fruits 2-3 in. long, oblong, orange-ed when ripe. Flowers and fruits in the rainy eason, and village boys when grazing cattle pluck he green fruits and take them home for cooking.

Coccinia indica W. & A. *Cephalandra indica* Naud. Cucurbitaceae)—vern., *kanduri. kundru.* An annual r perennial climber occurring in association with *Trichosanthes* sp., but distinguished from these by he 5-angled cordate leaves. Flowers white ; fruits blong, smooth, bright-red when ripe (Plate XIV, fig. 7). It flowers during and after the rains. The young reen fruits are used in curries and it is said to be ery useful for diabetics. Ripe fruits with sweatish pulp are eaten raw.

(ii) *Unripe fruits used in other ways*

Trapa bispinosa Roxb. (Onagraceae)—vern., *singhara.* An aquatic plant with floating leaves, sometimes found wild in the Najafgarh *jheels.* It is now much in cultivation. The spiny fruit is eaten raw after removing the shell. The powdered seed is used in many other ways.

Capparis aphylla Roth. (Capparidaceae)—vern., *karil, dela.* A much branched leafless shrub with spiny stipules ; flowers red, in elongated racemes ; berries $\frac{1}{2}$-$\frac{2}{3}$ in. in diameter, globose, red when ripe (Plate XIV, fig. 6). The flower buds and green fruit are pickled. As the shrub is quite common round about Delhi, poor people collect the green fruits and sell them in the bazar at the rate of about 6-8 annas a seer.

Acacia arabica Willd. (Mimosoideae)—vern., *kikar.* The tender pods are pickled in vinegar.

(iii) *Ripe fruits*

Capparis sepiaria L. (Capparidaceae)—vern., *heens.* The small round berries, black in colour, are sweet when ripe.

Grewia populifolia Vahl. (Tiliaceae). A shrub common on the ridge. Flowers white, fruits small, orange-red, available in early winter months. The well-ripened fruits are sweet and tasteful.

Zizyphus jujuba Lamk. (Rhamnaceae)—vern., *ber.* A medium-sized spiny tree with round fruits. Its fruits are much inferior to those of the grafted varieties ; those of some varieties irritate the throat. Fruits ripen in December-January.

Zizyphus nummularia W. & A.—vern., *jharberi.* A thorny bush very common in dry places. The fruits, which are smaller as compared to those of the preceding species, ripen in October-November about two to three months earlier than those of *Z. jujuba.* It has distinct botanical varieties in respect of earliness and lateness, size and taste of the fruit. Some of the varieties have fruits with flavour rarely possessed by the cultivated *ber.* A *ber* fruit with the size of the cultivated species and flavour of the best varieties of *jharberi* would be a very desirable fruit. Women of the surrounding rural areas collect the fruits and sell them in the market. The retail price of the fruit is 3 to 4 annas per seer. It is said that after attending to their domestic work, some women are able to collect as much as five seers of fruits daily.

Cucumis pubescens Willd., syn. *C. maderaspatanus* Roxb. (Cucurbitaceae)—vern., *kachra.* A creeping annual with reniform leaves and bright yellow monoecious flowers ; fruits oval, 3-4 in. long and 2-3 in. in diameter, usually spotted when ripe. Fruits ripen in September-October. The entire fruits including the seeds are edible when ripe.

Eugenia jambolana Lamk. (Myrtaceae)—vern., *jaman.* A large, evergreen tree, flowering in May. Ripe fruits which are oblong and dark-purple in colour come to the market in July. They are juicy and taken with a little salt are very acceptable. A round-fruited variety (*Eugenia jambolana* var. *microcarpa Thwaites*, vern., *jamoa*), with smaller fruits having little pulp inside is commonly found in rural areas. Its fruits are not so tasteful.

Salvadora oleoides Dcne. (Salvadoraceae)—vern., *jal, pilu.* A small evergreen tree common in the saline soils in *Khadar* and between the Grant Trunk Road and the Rohtak Road. Flowers appear in March and fruits ripen in May-June. The fruits are sweet and are commonly eaten. Another species, *S. persica* which grows in association with it has two varieties, one red-fruited and the other white-fruited. The red fruits have a characteristic irritating acidic taste, while the white ones are not acidic and are pleasant in taste. This species comes in

flower in November-December, about 2-3 months earlier than the true *jal*.

Cordia myxa L. (Boraginaceae)—vern., *lasura*, *lisaura*. A deciduous tree common in waste places round villages. It flowers during March-April and the fruits ripen from May to July. The fruits when ripe are round and light-brown in colour ; the viscid pulp which is sweet is edible. Ripe fruits are also pickled. (Plate XIV, fig. 8).

Cordia Rothii Roem. & Sch. (Boraginaceae)—vern., *gondni*. A small tree often cultivated. On the southern ridge this tree has become well established. The fruits which are ovoid and reddish-brown in colour are usually sold in the market. The pulp is not so viscid as in *lasura*.

Solanum nigrum L. (Solanaceae)—vern., *makoh*, *makoi*. An annual herb with dark green foliage. Flowers white, small, sub-umbellate. Fruits small round, orange or black. The black fruits are more tasty than the orange ones. A very common weed, flowering all the year round.

Morus alba L. (Moraceae)—vern., *tut*. Fruits are $\frac{1}{2}$-1 in. long, white or red, turning black when ripe ; they ripen in May-June. Common on the Grand Trunk Road as a road-side tree.

Ficus palmata Forsk. (Urticaceae)—vern., *anjiri*, *kaimbar*. A shrub or a small tree very similar to the cultivated fig.

Ficus carica L. Leaves 3-5 lobed. Figs axillary, solitary or in pairs, globose or pear-shaped, yellowish-purple when ripe. Figs ripen from June to October.

Ficus religiosa L.—vern., *pipal*. *Ficus bengalensis* L.—vern., *barh*, *barota*. *Ficus glomerata* Roxb. (*gular*). The fruits of these gregarious trees are also edible.

Phoenix sylvestris Roxb. (Palmae) ; wild date-palm—vern., *khajur*. A tall palm, quite common in Delhi province in waste places. Fruiting spadix long, drooping, golden orange in colour, appearing in April. Fruits about 1 in. long, orange-yellow in colour, ripening in May-June.

Fodder plants with special reference to famine conditions

The province of Delhi lies in an area which often experiences scarcity of fodder even in normal years. Over 60 per cent of the cultivated area of Delhi depends on the rains. Although the average annual rainfall of the province is about 22 in. in certain years, and not uncommonly for several years in succession, the total annual rainfall hardly exceeds 10 in. Thus the rainfall being insufficient and irrigation facilities meagre, the cultivator is often short of both food and fodder. In such times it becomes a matter of great urgency to find materials which could be utilized as substitutes. Since the starving cattle will eat almost any kind of plant, it is not to be assumed that all plants afford equally nourishing fodder and that all such plants can be called emergency fodder plants. In the latter category may be classed only those plants which are characterized by plentiful availability, succulence, digestibility and power to stand drought.

The following are the common 'famine fodder' plants of Delhi province :

Zizyphus nummularia W. & A. (Rhamnaceae)—vern., *jharberi*. In protected places it is a gregarious thorny shrub, but in places where they are subjected to frequent cuttings, the plants are rather small. The leaves form a most valuable fodder. The branches along with the leaves are cut and chopped into fine pieces with the help of a *gandasa* (Fig. 1) made by the village blacksmith. Since the branches

Fig. 1. A chopper (*gandasa*) made of an iron blade and a wooden handle

Fig. 2. A leather gripper (*hathal*) put on the hand

re spiny, these are handled with a leather gripper *uthal* (Fig. 2) made out of a coarse leather piece. he choppings are fed to the cattle alone or mixed ith *bhusa* if it is available. The leaves are also ored by beating the leaves off the cut branches nich have been dried previously. It is the xperience of the local cattle owners that the leaves romote the secretion of milk. Bushes are cut vice a year; once in March-April and again in ctober-November. But when there is severe famine ey are cut at any time of the year.

Acacia arabica Willd. (Mimosoidae)—vern., *babul, kar.* A moderate-sized spinescent tree, scattered l over the province. It is freely lopped for fodder; een pods, tender shoots and leaves being given cattle, goats and camels. It is specially useful r milch cattle, and is fed even in normal years for creasing theasecretion of milk. The data [Sen, 38] on the nalysis of green pods, ripe pods and ushed seeds given in Table I may be useful.

TABLE I

nalysis of green and ripe pods and crushed seeds of Acacia arabica

——	Total ash	Crude protein	Fibre
een pods . .	5·47	15·77	12·44
pe pods . .	6·24	14·64	16·5
ushed seed . .	7·43	14·64	14·8

Prosopis spicigera L. (Mimosoidae)—vern., *jand, gar.* An almost ever-green, moderate-sized thorny e whose loppings are valued for sheep, goats and mels. The pods which contain a sweet pulp are good food and are available in April-May.

Prosopis juliflora Dc.=*P. glandulosa Torr.* imosoidae); Mesquite bean. A fairly drought-isting plant, coming into leaf early in April, maining green right through the hot weather. It not indigenous to this area. It was first introduced the Horticultural Department and planted on e ridge. Later, it spread to the rural areas and some localities has become well acclimatized. It a useful source of famine fodder. The pods are ge, sweet, and succulent (Plate XV, fig. 1).

It is stated that the pods have a high nutritive lue, as shown by their contents, 8 lb. of digestible otein and 50 lb. of starch equivalent per 100 lb. of ds weight. They can thus be used to make up e protein deficiency of such roughages as wheat *usa* and rice straw which when fed alone do not nstitute a maintenance ration.

Some of the varieties grow into trees and are ful as a source of fuel.

Alhagi camelorum Fisch. (Papilionatae)—vern., *asa.* This thorny perennial shrub is very abundant all over the province especially in the alkali areas. It comes in leaf especially in hot weather. It is readily browsed by goats and sheep and is a special food of the camel. Tender branches are also given to the cattle after chopping. The pods are sweet. Flowers and fruits appear in May-June.

Dalbergia sissoo Roxb. (Papilionatae)—vern., *shisham, sisoo, tali.* A large deciduous tree, freely-lopped in times of fodder scarcity. According to Lander and Dharmani [1924] *shisham* leaves possess a feeding value comparable to that of green oats. But animals are not able to tolerate more than 5 to 6 lb. daily, excess causing diarrhoea. It can be made into fine silage. Fresh leaves are given mixed with *bhusa.*

Analysis of *shisham* leaves, according to the same authors, is given in Table II.

TABLE II

Analysis of shisham *leaves*

Moisture per cent	Dry matter	Ash	Crude fibre	Protein	Nitrogen free extract
71·54	28·45	2·95	5·59	5·11	13·65

The digestibility co-efficient is 143·35.

Ficus glomerata Roxb. (Urticaceae)—vern., *gular.* A large deciduous fast-growing tree found along the banks of the Western Jumna Canal near Bowana and along the Badarpur-Mehrauli Road. Green leaves and the fruits are much liked by cattle. A point in its favour is that the more it is lopped, the better is the growth of the leaf-bearing branches. Fruits are in clusters borne on short thick leafless branchlets arising from the trunks and larger branches, and number sometimes more then one hundred in a cluster (Plate XV, fig. 2). Thus there is a good yield of fruits also. Leaves and fruits are given alone. In the bazaars a small bundle of five to six twigs can be had for a pice.

Ficus religiosa L. (Urticaceae)—vern., *pipal.* A large tree with spreading branches. It is a sacred tree for Hindus who usually object to its being cut. It is however lopped for fodder by both Hindus and Mohammedans in times of scarcity. New leaves appear about the middle of March and fruits ripen from May to June. Branches with leaves and fruits are given directly to the cattle. Like *Ficus glomerata* it is a fast-growing and heavy-yielding tree.

Ehretia laevis Roxb. (Boraginaceae)—vern., *papri.* A small tree with rather broad leaves, scattered in this area. The tender twigs are cut and fed to the cattle.

Pluchea lanceolata C.B. (Compositae)—vern. *rukhri.* A small, hoary-pubescent shrub with erect

slender branches (Plate XV fig. 3). It is very common round Gangatoli, a village on the Western Jumna Canal. New branches appear in the month of March, and again during the rainy season when they are eaten away by grazing cattle. On flowering the branches become hard, when they are not relished. The leaves are succulent and saltish.

Chrysopogon montanus Trin. (Gramineae). A drought-resistant perennial grass growing very abundantly on the ridge. It can give several cuttings in a year. Although the plants grow quite tall, heavy yields cannot be expected on account of the leaves being narrow and present chiefly at the base (Plate XV, fig. 4).

Cymbopogon parkeri Stapf. (Gramineae). A rather dwarfish, perennial drought-resisting grass (Plate XV, fig. 5).

Eremopogon foveolatus Stapf. (Gramineae). A sporadic grass abundant in rocky and dry situations especially in the neighbourhood of the New Cantonment. It is perennial, flowering for most part of the year. A good fodder grass, about 1½-3 ft. tall; tillering moderate (Plate XV, fig. 6).

Cenchrus ciliaris L., and *C. setigerus* Vahl., (Gramineae)—vern., *anjan*. These are two important perennial pasture grasses, drought-resistant to a certain extent. For milch cattle they are very valuable. Fairly heavy yields are obtained.

Heteropogon contortus Beauv. (Gramineae). A good perennial fodder grass if used before flowering. The glumes have long twisted awns which make the plant unfit for feeding. It can give heavy yields on account of its high tillering and fairly tall habit.

During the rains a number of herbaceous plants come up in the cultivated fields and waste places. These are freely fed to the cattle as green fodder before *jowar* and *bajra* are available for the purpose. These are *Digera arvensis* Forsk., *Amarantus viridus* L., *Chenopodium album* L., *Celosia argentea* L., *Atriplex crassifolia*, *Echinochloa crusgalli* Beauv., *Dactylectenium aegyptium* Beauv. (*makra*), *Dicanthium annualatum* Stapf. (*apang*), *Eleusine indica* Gaertn., *Brachiaria ramosa* Stapf., *Brachiaria distachya* Stapf., *Urochloa panicoides* Beauv., *Aristida adscensionis* L. and *Digitaria bifasciculata* (Trin.) Henr.

In winter these weeds afford good fodder: *Convolvulus arvensis* L. (bindweed), *Lathyrus sativus* L. (*Khesari*), *Medicago denticulata* Willd. (*maina*), *Trigonella polycerata* L., *Melilotus alba* Desf., *Melilotus parviflora* Desf. (*senji*), *Vicia hirsuta* S.F. Gray and *Vicia sativa* L. (vetch).

Medicinal plants

Transport difficulties occasioned by war conditions have brought into great prominence the problem of medicinal requirements of this country. Efforts are now being made to collect information regarding the types of plants growing plentifully in nature in different localities both in the plains and in the hills, special attention being paid to the finding of suitable substitutes for those well-recognized pharmacoepial drug plants which may prove difficult to grow in India.

India being a vast country with a wide range of soil and climatic conditions, a large number of drug plants grow wild and others can be cultivated in localities most suitable for their growth. The collection of wild drug plants has certain disadvantages from the commercial point of view, and it is often more profitable to bring the more important plants into cultivation. In this connection it may be pointed out that as a first preliminary it is necessary to obtain accurate knowledge of the climatic and other conditions under which a plant would grow best, before undertaking its cultivation. It would be convenient if small areas were taken as the units of study and detailed observations were made on the time of flowering, fruiting, seed-setting, maturity and methods of propagation, etc. of the more important medicinal plants. It is hoped the information given below on the wild medicinal plants of Delhi Province will be useful in this respect.

Kirtikar and Basu [1938] described 1381 medicinal plants from the whole of India, out of which about 350 are cultivated. Of the remaining 1000 plants or so nearly 250 are met with as wild plants in the small province of Delhi. Again Chopra [1933] has given a glossary of 2200 medicinal plants growing in India, both wild as well as cultivated. About 350 plants from his list are found in Delhi, over 90 per cent being wild. Some of these are abundant while others are scarce.

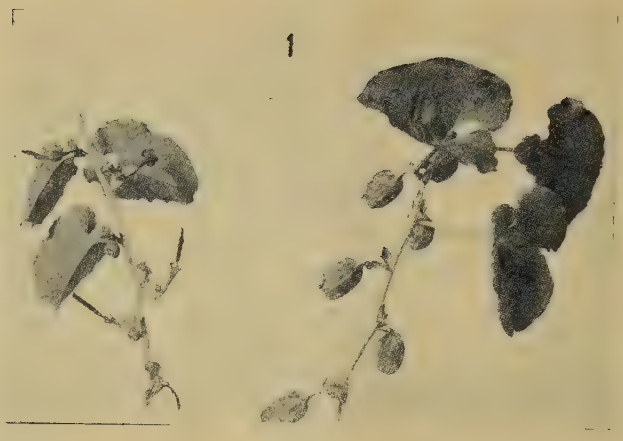
The more important plants are described immediately below. The notes regarding the uses of the plants are based on the two references cited above and upon information collected locally.

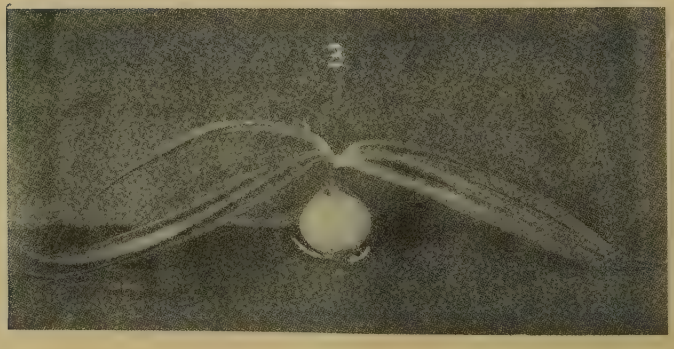
Argemone mexicana L. (Papaveraceae); Mexican poppy—vern., *kandiari*. An erect, annual herb common in waste places. Leaves spiny-toothed; flowers yellow; fruit a prickly capsule containing black globose seeds. Flowers in winter, seeds ripening in April-May. The yellow latex is used in dropsy and jaundice. It is also used by local *vaids* in the preparation of certain ointments. The seeds yield about 22 per cent of argemone oil used in the treatment of ulcers. The oil contains small quantities of berberine.

Aristolochia bracteata Retz. (Aristolochiaceae)—vern., *kiramar*. A slender, prostrate, perennial herb with glaucous leaves. The perianth is very characteristic in having a sub-globose base, cylindrical tube and a trumpet shaped dark purple mouth. The fruit is a 12-ribbed glabrous capsule about 1-1½ in. long. Flowers over the greater part of the year (Plate XVI, fig. 1). It is an extremely bitter plant

Wild fodder plants.

FIG. 1. *Prosopis juliflora*, a cluster of pods.
FIG. 2. *Ficus glomerata*, a cluster of fruits.
FIG. 3. *Pluchea lanceolata*, an entire plant, before flowering.
FIG. 4. *Chrysopogon montanus*, an entire plant in flower.
FIG. 5. *Cymbopogon parkeri*, an entire plant, in flower.
FIG. 6. *Eremopogon foveolatus*, an entire plant in flower.





Wild medicinal plants.

FIG. 1. *Aristolochia bracteata* a : a branch showing flowers on the under surface ; b : a branch showing fruits.

FIG. 2. *Vitis trifolia*, a tri-foliate leaf and a tuberous root.

FIG. 3. *Urginea indica*, a bulb along with leaves.

d is used as an anthelmintic. The roots are said to used as a substitute for ergot. It is also reputed be an antidote to snake poison.

Achyranthes aspera L. (Amarantaceae)—vern., *rchitta.* A common weed of waste places, charac-ized by long rigid spikes and inconspicuous flowers th spinescent bracts and bracteoles. Flowers almost roughout the year. Flowering spikes and seeds e used for snake bite. A decoction of the whole nt is given in renal dropsy.

Acacia arabica Willd. (Mimosoidae)—vern., *bul, kikar.* A moderate-sized evergreen spinescent e. Leaflets 10-20 pairs, flowers in yellow globose ads. Fruit a 3-6 in. long, beaded pod. Flowers ring the rains and winter. Pods ripen in March-pril. The bark is an excellent astringent and is ed in chronic diarrhœa. Its chief uses are as an tringent douche in leucorrhoea and vaginal dis-arges, as an enema in piles, and as a mouth-wash.

Artemisia scoparia Waldst. and Kite. (Com-positae). A perennial herb 3-6 ft. high ; stem tinged th purple ; leaves pinnatisect with linear segments ; wer-heads yellow. It grows in dry, sandy places d flowers after the rains.

As several other species of *Artemisia* contain the ug santonin, it is quite possible that this species ay also possess it. It is used as a purgative.

Boerhaavia diffusa L. (Nyctaginaceae). A very mmon prostrate herb with thick, glabrous, unequal aves. Flowers pink, arranged in small umbels. grows well in dry places and flowers practically roughout the year.

It contains the alkaloid punarnavine, an injection which increases blood pressure ; also used in æmia and heart diseases. The plant contains preciable quantities of potassium nitrate.

Butea monosperma (Lam.) Kuntze ; syn. *B. ondosa* Koen. ex Roxb. (Papilionatae)—vern., *ilas, dhak.* A medium-sized tree growing on the dge. It comes into flower in March and April, hen it presents a strikingly beautiful appearance n account of its handsome orange flowers. Pods re 4-8 in. long and are very velvety.

It is a useful tree because (*a*) its gum is used as an stringent, (*b*) the flowers and leaves are astringent, iuretic and aphrodisiac, and (*c*) the powdered seeds re used as an anthelmintic.

Balanites aegyptiaca Delile (Simarubeae)—vern., *ingot.* A shrub or small spiny tree, common on the orthern ridge ; flowers greenish white ; fruits about in. long with a hard rind and pulpy inside. Flowers April-May.

The fruits possess purgative anthelmintic and, xpectorant properties ; also used in cases of snake te. The active principle is saponin.

Chenopodium ambrosoides L. (Chenopodiaceae). n annual or perennial foetid herb growing in moist laces, flowering throughout the year. The well known oil of chenopodium, used in the treatment of round worms, is derived from this plant. It is not definitely known, but appears worth testing if the local variety can be profitably used for the extraction of the oil. The pre-war price of the oil was Rs. 32 a lb.

Citrullus colocynthis Schrad. (Cucurbitaceae) ; colocynth—vern., *indrayan, kaurtumba.* A perennial trailing herb common in sandy tracts near Nangloi and Narela. The plant resembles *C. vulgaris* (water-melon) except in the fruit which is small, up to 3 in. in diameter, and very bitter (the bitter substance is colocynthin). It is a drastic purgative and in the form of solid extract enters into many of the purgative pills of modern pharmacy. There is a good demand for the pulp of the fruits.

Cleome viscosa L. (Capparidaceae)—vern., *hulhul.* An annual herb growing very plentifully during the rainy season in waste places, especially in rocky situations ; leaves 3-5 foliate ; flowers yellow ; capsule 2-3 in. long ; seeds black.

The juice of the leaves mixed with warm *ghee* is used in earache. The seeds are more important, being efficacious as an anthelmintic and as a counter-irritant in chronic painful joints. The seeds are sold at twelve annas a seer in the bazaars of Delhi.

Corchorus antichorus Roeusch. (Tiliaceae)—vern., *boh-phali.* A prostrate, much branched, perennial herb with woody stems ; flowers yellow ; capsule cylindric, about $\frac{1}{2}$ in. long. It is common in waste places and new shoots come up in the rainy season.

The whole plant is locally used in the treatment of gonorrhoea. In the bazaars of Delhi, especially in the Chandni Chowk old women bring locally collected basketfuls of this herb for sale.

Cissampelos pareira L. (Menispermaceae)—vern., *Nirbsi.* A twining shrub common in the gardens on the Rohtak Road. Leaves are orbicular in shape ; fruits are small, subglobose, scarlet when ripe. Flowers during the rainy reason.

The dried root of the plant is a common bazaar drug. A decoction of the root is used as a diuretic and also in bowel complaints. Leaves are used in sores and itches. Three alkaloids, viz. sepeerine, bebeerine and cissampeline, have been shown by analysis to be present.

Fumaria parviflora Lamk. (Fumariaceae)—vern., *pitpapada* or *papra.* An annual, often scandent herb with much divided leaves ; flowers purplish in leaf opposed racemes ; fruits small, globose. It is abundant in cultivated fields as well as waste places, flowering during winter. It contains the alkaloid fumarine.

A decoction of the plant which is very bitter is locally used for blood purification. In this respect it is used as a substitute for *Swertia chireta* (*chiraita*) which grows chiefly in the hills.

Adhatoda vasica Nees. (Acanthaceae)—vern., *arusa, basuti*. An evergreen shrub 4-8 ft. high. Flowers white, in dense spikes 2-4 in. long ; capsule 1 in. or more in length. The plant is common throughout the province.

The active principle is an alkaloid called vasicine found in the leaves. The fluid extract prepared from the leaves relieves cough and liquifies sputum.

Lippia nodiflora Rich. (Verbenaceae). A widely creeping, much branched perennial herb. Flowers sessile, white or pinkish, arranged in dense globose to oblong spikes. It is very common in the *Khadar* tract. It is often seen in the grassy lawns of Delhi irrigated with river water.

The plant is used as a febrifuge and as a diuretic. Local people use the flowering and fruiting spikes in treatment of small pox.

Polygala chinensis L. (Polygaleae). An erect or diffuse annual 6-12 in. high with narrow linear leaves ; flowers light purple. Common in light soils and flowers for the greater part of the year.

It is a good substitute for *Polygala senega*, an American plant. It contains senegins resembling saponin. Preparations of this plant are used in chronic bronchitis.

Sida cordifolia L. (Malvaceae)—vern., *bijband*. A small erect shrub with cordate leaves ; flowers small, yellow. It is a common weed, flowering during the rains and the cold season.

It is considered to be one of the most valuable drugs in Ayurvedic medicine. The plant contains small quantities of ephedrine hence its use as a cardiac stimulant. The seeds are used in leucorrhœa, spermatorrhœa and gonorrhœa.

Sisymbrium irio L. (Cruciferae)—vern., *khubkalan*. An erect annual, 1-3 ft. high, common everywhere as a weed of the cold season. The seeds ripen in March ; they are small, roundish, yellow to brown in colour.

The seeds are expectorant, stimulant and restorative, and are used frequently in asthma. In the Delhi bazaars, seeds are sold at the rate of 8 to 12 annas a seer. The seeds of an allied species, *S. sophia* L. , are also used as a substitute for the above.

Solanum xanthocarpum Schrad. (Solanaceae)—vern., *kateli*. A prostrate perennial herb with prickles all over the plant ; flowers bluish purple, in small cymes ; fruits small, yellow when ripe, $\frac{1}{2}$-$\frac{3}{4}$ in. in diameter. It is quite common in waste places, flowering and fruiting almost all the year round.

Its chief uses are as a cardiac tonic and as a carminative. It is also useful in asthma. Locally the fruits are applied, after crushing, on sores.

Urginea indica Kunth. (Liliaceae) ; Indian squill—vern., *Jangli piyaz*. A herb with tunicate bulbs ; leaves radicle, linear ; flowers drooping, arranged distantly on a long leafless scape, often appearing before the leaves. Bulbs are 2-3 in. long. It grows commonly on the northern ridge, almost amongst the stones. The flowering scapes appear in March-April (Plate XVI, fig. 2).

The Indian squill has been found to be in no way inferior to the imported varieties of *Urginia scilla* and *U. maritima*. The bulbs possess cardiac stimulant and diuretic properties.

Vitex negundo L. (Verbenaceae)—vern., *sambhalu*. A tall shrub with thin gray bark ; leaves 3-5 foliate. Flowers blue, in cymes, forming terminal panicles. It grows commonly in the *bangar* tract on the raised bunds along the unmetalled roads. Flowers over the greater part of the year.

It is a common bazaar drug. The heated leaves are applied to painful and rheumatic swellings. Macerated leaves, made into a paste, are given as a cooling application on the forehead in headache.

Vitis trifolia L. (Ampelideae)—vern., *nirbsi*. A slender climber with 3-foliate leaves ; leaflets 1-3 in. long, ovate-lanceolate, dentate ; cymes axillary, 3-5 rayed with many cymose branches ; flowers greenish white ; fruit a small globose berry. New branches appear after the first shower in the rainy season. Fruits ripen in September-October.

The tuberous roots (Plate XVI, fig. 3) are locally used in the case of snake bites. The leaves are often used in the form of a poultice in the treatment of boils.

In addition to the above there are a number of other plants some of which are common bazaar drugs and others are important because they contain important active principles. These are listed below ; *Acalypha indica* L., *Anagallis arvensis* L., *Asphodelus tenuifolius* Cavan., *Alhagi camelorum* Fisch., *Ailanthus excelsa* Roxb., *Coldenia procumbens* L., *Cannabis sativa* L., *Cressa cretica* L., *Cassia occidentalis* L., *Cassia obtusifolia* L., *Calotropis procera* R. Br., *Cardiospermum helicacabum* L., *Cocculus villosus* Dc., *Datura fastuosa* Nees., *Euphorbia hirta, Gynandropsis pentaphylla* Dc., *Hygrophila spinosa* T. And., *Lochnera pusilla K. Schum, Oldenlandia corymbosa* L., *Trichodesma indicum* Br., *Verbascum thapsus* L., *Volutarella divaricata* Benth., *Withania somnifera* Dunal., *Xanthium strumarium* L.

Fresh branches with flowers and young fruits attached of a number of wild plants are sold in Delhi for medicinal purposes. Small shops dealing with such plants are attached to some of the important *Unani Dawakhanas*. The more common plants of this nature are listed in Table III. It may be mentioned here that there is only a limited demand for these plants in this form.

Ornamental plants

Gardens in India are not, as a rule, noted for the variety of herbs and shrubs grown and it is hoped that the notes given below will be of use to those garden-lovers who are interested in out-of-the

TABLE III

Wild plants sold for medicinal purposes

me adopted by salesmen	Botanical name	Price per seer of the branches (in annas)
rbel . .	*Cuscuta reflexa* Roxb. .	4
nd . .	*Withania somnifera* Dunal.	2
ang . .	*Plantago major* L. .	4
hmi . .	*Hydrocotyle asiatica* L.	6
ti . . .	*Adhatoda vasica* Nees. .	2
ua . . .	*Chenopodium album* L. .	2
nbuti or *Jalbuti*	*Lippia nodiflora* Rich. .	2
angra . .	*Eclipta alba* Hassk. .	6
sa . . .	*Alhagi camelorum* Fisch.	3
ep . . .	*Herpestis Monnieria* H. B. & K.	6
lu . . .	*Diospyros cordifolia* Roxb.	2
hhechhi . .	*Polygonum plebejum* L. .	8
oh . . .	*Solanum nigrum* L. .	2
ukchun . .	*Heliotropium strigosum* Willd.	4

nary things and are prepared to do a little erimenting with new plants. For the sake of venience the ornamental plants have been divided ghly into four groups according to the seasons in h they flower: winter plants (November to ruary); spring plants (March-April, although real ng is of very short duration); hot weather plants -July); rainy season plants (August-October).

ter plants

ngallis arvensis L. (Primulaceae). An annual, umbent herb, 6-12 in. tall, with opposite- ssate leaves. Flowers bright blue, arranged on opposite, axillary peduncles.

idens pilosa L. Compositae. An erect annual, ft. tall, with trifoliate leaves. Ray florets are e and disc florets yellow.

rotalaria sericea Retz. (Papilionatae). An erect, ual or perennial, robust, undershrub, 3-5 ft. . Flowers yellow tinged with purple, large, nged in branching terminal racemes. Flowers ughout the year in moist situations.

elsia coromandeliana Vahl. (Scrophulariaceae). nnual herb 1-3 ft. high, with leaves of different es on the same plant. Flowers yellow, in le or branched terminal racemes, often forming rge terminal panicle. The plant is beautiful n in full bloom.

anunculus sceleratus L. (Ranunculaceae). An annual, common near water. Flowers yellow blong heads. It is common at Okhla.

ponaria vaccaria L. (Caryophyllaceae). It is dy a garden plant and is quite common in the s in this area.

Silene conoidea L. (Caryophyllaceae). An erect dichotomously branched annual, 6-18 in. high. The flowers which have an elongated, inflated calyx tube and cross-shaped pink petal lobes look quite handsome.

Verbascum thapsus L. (Scrophulariaceae). The plant resembles tobacco in the vegetative stage. Spikes up to 2 ft. long. Flowers yellow, much crowded, giving the spikes a cylindrical appearance.

Spring plants

Arnebia hispidissima Dc. (Boraginaceae). A more or less prostrate, hispid herb with bright yellow tubular flowers in compact one-sided scorpioid cymes.

Butea monosperma (Lam.) Kuntze. (Papiloniatae). The Flame of the Forest; a medium-sized tree. Flowers bright orange red, large, in axillary and terminal racemes. The leaves generally appear after the flowering is over.

Capparis aphylla Roth. (Capparidaceae). Red flowers in elongated racemes on leafless branches present a striking sight and are useful for cutting.

Erythraea ramosissima Pers. (Gentianaceae). A small delicate annual, common in moist places and lawns. Flowers pink, arranged in dichotomous cymes. A short-lived plant, 6-10 in. high.

Pulicaria crispa Benth. (Compositae). A perennial much branched herb, 1-2 ft. tall. Heads yellow, solitary. The plant looks beautiful when in full bloom. It does not require much care.

Tecomella undulata Seem. (Bignoniaceae). A medium-sized tree. It is one of the most beautiful ornamental trees when in flower. Flowers orange-yellow, fairly large, in corymbose racemes. Not very common in this area.

Hot weather plants

Cryptostegia grandiflora Br. (Asclepiadaceae). A large evergreen climbing shrub with thick glossy foliage and large handsome pink, funnel-shaped flowers. Very common at Okhla. It is however not truly wild.

Rainy season plants

Commelina nudiflora L. (Commelinaceae). A diffuse annual herb with prostrate or subscandent branches; leaves lanceolate; cymes enclosed in spathaceous bracts, flowers blue.

Ipomea hederacea Jacq. (Convolvulaceae)—vern., *nilkalmi*. An annual twining herb with trilobed leaves. Flowers blue, funnel-shaped, quite pretty, appearing in August-September.

Lantana indica Roxb. (Verbenaceae). A tall shrub with straggling branches. Flowers white, arranged in axillary heads or spikes.

Leucas aspera Spreng. (Labiateae). An annual 6-18 in. high. Flowers white, sessile, in terminal

and axillary distant whorls up to 1 in. in diameter. The globular flowering heads are rather attractive.

Rivea hypocrateriformis Chois. (Convolvulaceae). A large climbing shrub with white, clove-scented flowers. Common near the 'Malcha View' on the ridge.

Ruellia prostrate Lamk. (Acanthaceae). Commonly found in moist and shady places amongst the bushes. Flowers bluish purple, funnel-shaped.

Vicoa vestita Benth. (Compositeae). A much branched, fairly tall, annual herb with bright yellow flowers in discoid heads.

Material for plant breeding work

There was a time when wild plants were considered to be of interest to the taxonomist only, and plant breeders limited their breeding experiments to the existing cultivated varieties. After a time, however, it became apparent that, in the case of many crops, the limit of improvement on this basis had been reached and it was necessary to discover or introduce new genes and to devise new ways of combining them with the old genes. It is now known that many wild or little-known species or varieties related to our cultivated plants exist and it not infrequently happens that these are resistant or immune to some of the diseases that exact such a heavy toll from their cultivated relatives. Sometimes they are able, again unlike the cultivated varieties, to thrive under conditions of severe cold, heat or drought. Modern plant breeders therefore are keenly interested in wild forms and the possibility of transferring valuable genes from these to the cultivated varieties, and numerous expeditions have been organized within the last two decades or so to search for new genes. Outstanding leadership in this direction has been shown by Dr Vavilov of Russia. The use of wild plants in breeding has also received stimulus from the discovery that by the use of colchicine chromosome numbers can be doubled, leading to the consequence that sterile hybrids resulting from wide crosses can be made fertile.

The plants described below appear to merit the attention of the plant breeder. It is hardly necessary to point out that plants which flourish in the dry scrubby portions of Delhi Province, especially the exposed portions of the ridge, possess in abundance drought resistance and hardiness.

Carthamus oxyacantha Bieb., wild safflower—vern., *Poli*, *Kasumbhi*. Although low in oil content, it is exceedingly hardy and drought-resistant. It is also somewhat resistant to *Acanthiophilus helianthi*, an insect which causes great damage to the flower heads of the cultivated safflower (*Carthamus tinctorius*). By suitable hybridization it may be possible to combine this resistance with high oil content. It is a very common weed in *rabi* crops.

Hibiscus micranthus L. (Malvaceae). A fib plant commonly growing as a perennial shrub on t ridge almost amidst the stones. The plant gro quite tall. It may be worthwhile exploiting th plant from the fibre point of view. It has also be observed that it is not as highly susceptible to fr as *H. cannabinus* and *H. Sabdariffa*.

Corchorus spp. (Tiliaceae). Several species *Corchorus* allied to *C. capsularis* (the jute plant), vi *C. olitorius*, *C. trilocularis*, *C. acutangulus*, a *C. antichorus* grow in a wild state. Delhi soil apparently very well suited for *C. olitorius*, certa varieties of which are cultivated for fibre chie in Bengal. It would be worth investigating if a of the above species could be made use of in t improvement of the jute plant.

Crotalaria spp. (Papilionatae). *C. sericea*, *burhia*, *C. mysorensis* and *C. medicaginea* are a fe wild species met with in this tract; the former t are perennials and the latter two are rainy seas annuals. The following points require investig tion with regard to the above species:

1. Whether the leaf size of *C. sericea* could introduced into *C. juncea*, with a view to produci a better fodder and green-manuring plant. Attemp at crossing these species have so far been unsuccessf

2. What is the green manuring value of the species as compared to the common sunn-hemp.

3. Breeding of an early maturing *C. juncea* making use of *C. mysorensis* which is an ea maturing species.

From the fibre point of view all these species see to be undesirable on account of their branching low heights.

Plantago spp. (Plantaginaceae). Several species *Plantago* viz. *P. ovata* (*isaphgol*), *P. amplexicaul* *P. pumila* and *P. major* grow in a wild state.

Although locally no use is made of these plants t fact that *P. ovata* grows wild indicates the suitabili of this tract for its cultivation. It is an importa drug plant, the seeds of which are used in the trea ment of a number of diseases, specially dysent The possibility of utilizing the species other th *P. ovata*, directly or indirectly in the improveme of *P. ovata* or *P. psyllium* (B.P. Plant) is wor investigating. *P. ovata* and *P. major* are genera found in moist situations whereas *P. amplexican* and *P. pumila* are generally found in dry roc places.

Nicotiana plumbaginifolia Viv. (Solanaceae). annual herb common at Okhla and near the Jum bridge. It is apparently resistant to virus but co tains only negligible quantities of nicotine. seeds can be collected in May.

Solanum incanum L. (Solanaceae). A perenn shrub much resembling the egg-plant, *S. melonge* L. It has small round bitter fruits about 1 in. diameter; flowers and fruits appearing in the rai

eason. It is fairly resistant to drought and the oot borers. It may be useful in the improvement f the egg-plant since it crosses easily with it when e egg-plant is used as the male parent. The itterness of the fruit is dominant in the F_1. By itable crossing it should be possible to isolate a lant free from bitterness.

Lolium temulentum L. (Gramineae). The genus *olium* is allied to *Triticum* and *Hordeum*. *Lolium mulentum* is rust and possibly smut resistant, but ot resistant to drought. It has a high tillering apacity and produces a fairly large number of rains per plant as compared to wheat and barley. lthough past attempts at crossing this with wheat ave not been successful, it is possible that systematic ytlic crossing with wild and cultivated wheats and arleys with different chromosome numbers may lead o success.

Urena lobata L. (Malvaceae); Aramina. It ccurs as a perennial weed and a number of plants an be seen in waste places along the Shahdra Road. t furnishes a yellowish white fibre that is said to be ore lasting than jute and as such is used as a ubstitute in many industries. It is grown commerially in Cuba, Madagascar and Brazil where it is hiefly used in making coffee sacks. It is worthwhile xperimenting with the quality and economics of he local variety from the fibre point of view.

Other useful plants

Cryptostegia grandiflora R. Br. (Asclepiadaceae). the present war it has received attention as a ossible war-time source of vegetable rubber. At khla on the right bank of the river there is a strip out $1\frac{1}{2}$ miles long and a furlong wide having big ushes of this plant said to be more than 25 years .

Vetiveria Zizanioides Nash. (Gramineae). A erennial grass much resembling the wild *saccharum* S. *spontaneum*) in the vegetative stage. The roots nd rhizomes of this plant yield oil of vetiver, much sed in perfumery. It is not very common but it an be grown very easily for commercial purposes.

Sapium sebiferum Roxb. (Euphorbiaceae); hinese-Tallow tree. A medium-sized tree superfiially resembling *Dalbergia sissoo*. A number of rees of this species can be seen in the Subzimandi ardens, and probably it is a moisture-loving plant. he seeds yield a drying oil which is in great demand. he thick layer of hard white fat on the seeds of this lant is the source of Chinese vegetable tallow.

Bombax malabaricum DC. (Bombacaceae); *emal*, and *Calotropis procera* Br., Asclepiadaceae; *kha*, yield silk cotton which is the best material for uffing pillows etc. The mature woolly spikes of *erua tomantosa* Forsk. (Amarantaceae) can also e used for the same purpose.

Typha angustata Chaub. & Bory. (Typhaceae)—*patera*. It grows abundantly in ditches near Okhla. The leaves are used for thatching and for making mats. A poor quality rope is also made out of the leaves.

Tamarix dioica Roxb. (Tamaricaceae)—vern *jhau*. A shrub with long spreading or drooping branches. It is very common in this area especially in river beds and waste alkaline places. The branches are used for making brooms and baskets. Every year there is a regular auction of these *jhau* thickets.

Desmostachya bipinnata Sta.=*Eragrostis cynosuroides* Retz. (Gramineae);—vern., *dhab*. The culms make a broom which in the opinion of the local sweepers lasts twice as long as the brooms generally used in the houses.

Saccharum spontaneum L. (Gramineae); wild Saccharum—vern., *kana, sarkanda*. The culms are extensively used for making 'chicks'. Entire plants are used for thatching purposes. Very common all over the province.

Xanthium strumarium L. (Compositeae). A fairly tall, scabrid, annual, growing in low-lying places where there is accumulation of water. Fruits have short tubercles and as such the plant is considered to be a harmful weed on account of its fruits sticking to the wool of the grazing sheep. Recently it has been found by Russian workers to be a new oil plant with commercial possibilities. The seeds yield 34 per cent oil. The oil has high specific gravity and resembles linseed oil as regards iodine number; its saponification value is also high. In all these points it takes priority over sunflower and castor oils. The plant is quite common in this area.

Summary.

About one hundred and fifty important wild plants of the Delhi Province have been classified according to their uses, under six heads, viz. (1) edible plants, (2) fodder plants with special reference to famine conditions, (3) medicinal plants, (4) ornamental plants, (5) material for plant breeding work, and (6) other useful plants. A brief botanical description of each plant and common English and vernacular names and places of common occurrence within the province of the more important plants are given. The notes regarding the uses of the plants are based on the references cited in the text and also upon the information collected by the author from the local people while surveying the area for plant collection.

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RANDOM SAMPLING FOR ESTIMATING RICE YIELD IN MADRAS PROVINCE

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In a previous paper [1945] the author has reviewed the problem of estimating the yield of food grain crops in India by the method of random sampling and described the results of an experimental survey on wheat in the Punjab conducted in 1944. A brief account of the plan adopted for the survey and the results obtained has also appeared in *Nature* [1944]. The survey was carried out over an area of 88,000 sq. miles and was probably the first of its magnitude to be carried out in this country. The field work was carried out by the staff of the Department of Agriculture, Punjab. Briefly, the plan adopted for the survey was as follows :

A total of 748 villages was selected. These were for each district of the province proportionate in number to the area under wheat but equally distributed among the *tahsils* of the district and randomly within each *tahsil*. Within each village three fields were selected, and within each field one plot, 1/20th of an acre. The selection of the fields in villages and of the plot in each field was by the use of random numbers supplied by the Centre which was able to check the process. Harvesting, threshing, winnowing and weighing were normally completed in one day. The final estimate included adjustments for driage. The sampling error of the estimated yield was only just over one per cent. The survey showed that it is feasible to use the method of random sampling by the existing departmental staff for estimating the yield for each district and the province without heavy additional expenditure.

As a preliminary step for extending the survey to other food grain crops on an all-India basis, pilot surveys on small scale in one district each of the provinces of Bombay, Central Provinces, and Madras were undertaken with the objects of (*a*) testing the efficiency of the technique so far developed for estimating the yield of paddy and improving it where necessary, and (*b*) for gaining information on the practical difficulties peculiar to paddy crop likely to be encountered in the field work. The results of the survey conducted in the Tanjore district of the Madras Province and their bearing on the technique of random sampling are described in this paper.

Tanjore was selected for the scheme since it has the largest acreage under paddy and is typical of the deltaic region of the Madras Province. It is divided into 11 *talukas* covering an area of 3,738 sq. miles, of which approximately 55 per cent is under paddy. It is for the most part a plain irrigated tract receiving ordinarily a rainfall of 30 in. It contains 2,437 villages.

The field work was organized under the charge of an Agricultural Officer appointed for the purpose. The field staff consisted of the local Agricultural Demonstrators, who ordinarily carry out the experiments. The choice of the local agricultural staff to carry out these experiments was governed by the consideration that any new technique that might be devised will ultimately have to be worked out by these men and no other. There were 22 Agricultural Demonstrators in all. They were assisted by fieldmen, maistries and messengers. All the Agricultural Demonstrators were men with considerable practical experience and had knowledge of the tract and of the rice crop.

The plan adopted for the survey was the stratified plan of sampling with *talukas* as the strata, a village as the primary unit of sampling, a field as the subunit of sampling and a plot 1/20th of an acre as the ultimate unit of sampling. A total of 132 villages representing approximately 5·4 per cent of the total number of villages in the district was selected. They were divided equally among the 11 *talukas*. The villages were randomly selected separately in each *taluka*. The selection was done in the Statistical Section at New Delhi, since it was anticipated that considerations of distance and lack of communications and other difficulties might weigh with

e provincial staff and be allowed to interfere with e random character of the sample.

In each selected village three fields were selected random. The selection of fields was confined to e main Samba crop and to the second crop of ddy. Within each selected field a plot measuring ft. × 33 ft. was located at random. The choice one plot per field was deliberately made as previous sults had shown that the variation within field tween plots of the size of 1/20th of an acre was gligible as compared with the variation between llages within *taluka* and between fields within llages. The plot was divided along the length to six equal strips 11 ft. × 33 ft. each. If one or ore of the villages did not contain the requisite mber of fields growing paddy, they were to be jected and substituted one by one by the villages the supplementary sample in the order given. ctually, however, all the villages originally selected ere found to contain the requisite number of paddy lds.

A detailed set of instructions was drawn for the idance of the staff for (*a*) selection of fields, (*b*) cation of plots, (*c*) harvesting and connected erations, and (*d*) driage. Although the fields were lected in advance, to ensure that all the fields the villages got an equal chance of being sampled, e plots were marked on the dates on which the oduce was harvested. All the operations of harsting, threshing, winnowing and weighing were rried out by the Agricultural Demonstrators sisted by fieldmen, and were supervised by the ficer-in-charge.

Three forms of returns were prescribed under the structions. In Form 1, the Agricultural Demonsator was required to state the survey numbers the fields selected, the pair of random numbers locating plots in respect of each selected field, e type and level of the soil, the name of the preding crop, the name and quantity of manure, the ariety of paddy, the estimated yield in pounds er acre, the revenue estimate of yield in annas d, finally the date fixed for harvesting. He was so asked to give detailed remarks in regard to the neral condition of the crop. The form was reired to be sent at New Delhi immediately after e selection was over. Under Form 2, the Agriltural Demonstrator was required to fill in the tual results of harvesting in respect of each strip plot in the village. He was specially asked to te any changes in the condition of the crop that ok place since the fields were selected. The return as required to be sent immediately after the harsting for each field was over. Form 3 sets out e results of re-weighment of 20 lb. of harvested ddy after the period of about a fortnight.

In addition to the scheme outlined above, a special quiry was undertaken in the *taluka* of Tanjore for investigating the possibility of using a paddy-growing field itself as the ultimate unit of sampling. The enquiry consisted in harvesting the whole of the field after the selected plot was harvested. As, however, the produce in the whole field was too large to be fully hand-threshed and winnowed without loss of grain, it was threshed in the manner practised by the cultivators. This practice consists in hand-threshing the produce on the day on which it is harvested and in cattle-threshing it after a period of about a fortnight. To ensure speed and accuracy, however, in the present scheme the produce was cattle-threshed on the morning next to the day of harvesting.

Uniformity of produce was obtained by central training of the staff in all the details of the scheme. Firstly, the field staff were gathered at the headquarters of the District Agricultural Officer, where the plan of work, the duties and responsibilities of each member of the field staff, the meaning and implications of the instructions drawn for the actual conduct of field work, the manner in which the returns were to be filled and despatched, were read out, explained and discussed at length several times over until the workers, particularly the Agricultural Demonstrators, obtained a clear idea of the entire procedure of work. It was impressed upon them that the work they were doing was of very great importance, especially during the emergent food situation of the present time, and demanded extreme scientific honesty. The training was completed with practical exercises in the fields of Malaveli village near Tanjore.

The Agricultual Demonstrators were fully equipped with all the experimental articles. They had their own measuring chains and were supplied with coir strings, scales and weights, bamboo sticks, gunny pieces of cloth and bags. As for the cross-staffs for marking right angles, the Karnams of the selected villages were instructed to lend them to the Agricultural Demonstrators. They were provided with the requisite number of copies of various returns and sets of instructions and random numbers.

There were two Agricultural Demonstrators in each *taluka* each in charge of six villages (18 fields). Altogether, a total of 396 fields were selected under the scheme. Out of this total, experiments were performed in all fields except one, where the crop was harvested before the due date.

The cultivators of all the selected fields willingly agreed to have the experiments done in their fields. They readily arranged for the labour required for harvesting and in return were paid fixed amounts towards labour charges. As a rule, wherever possible, the operations of harvesting, threshing and winnowing were done on the same day, but in a few cases where the produce was moist, it was allowed to dry up for a day or two before it was

threshed. The produce obtained was invariably weighed with the help of standard weights purchased by the Agricultural Demonstrators. The work was inspected by the Officer-in-charge, who toured for 83 days, visited 63 villages and helped the Agricultural Demonstrators in marking the plots and in conducting the harvest of the experimental strips.

The returns which numbered about 400, were scrutinized in the Statistical Section of the Imperial Council of Agricultural Research at New Delhi as they came in. The scrutiny showed that the random numbers were correctly used both in the selection of fields and in the location of the plots. Wherever a discrepancy was noted it was promptly referred to the person concerned.

The season was not favourable on the whole. It was marked by abnormally wet weather in November. The crop was also badly affected by pests and diseases, particularly the stem-borer, the *Soorai* and blast.

Table I shows the results in respect of the average estimated yield of paddy (in husk) and of rice for each *taluka* and for the district as a whole, together with the sampling errors. In this table the name of the *taluka* is given in column 1, the number of experiments in column 2, the average weight of dried paddy in pounds per acre in column 3,* the average weight of rice in pounds per acre (taking rice at $\frac{2}{3}$ the weight of dried paddy) in column 4, the standard error of the average weight of dried paddy in column 5, the standard error expressed as percentage of the yield estimates in column 6, and the eye-estimates of paddy in annas and in pounds per acre in columns 7 and 8. The last row of the table shows these figures for the district as a whole. The district average is only a simple arithmetic average of the *taluka* figures. The method of calculating the standard error is explained later on.

*An allowance for driage based on the results given in Form 3 has been made in calculating the figures in this column. This allowance varies from 6 to 13 per cent for the different *talukas*.

TABLE I

(Tanjore, 1944-45)

Average yield in each taluka *with its sampling error*

Name of *taluka*	No. of plots	Average weight of dried paddy in lb. per acre	Average weight of rice in lb. per acre	Standard error of the average weight of dried paddy in lb. per acre	Percentage sampling error	Revenue estimate in annas	Eye-estimate in lb. per acre
Tanjore	36	1324·57	883·05	172·52	13·04	7·1	981·67
Kumbakonam	36	1318·94	879·29	101·03	7·66	8·5	1395·56
Papanasam	36	1540·88	1027·25	86·44	5·61	7·6	1475·83
Mayavaram	36	1553·51	1035·67	87·62	5·64	7·9	1403·33
Shiyali	36	1546·72	1031·15	105·79	6·74	7·8	1395·14
Nannilam	36	1555·29	1036·86	79·16	5·09	8·1	1468·33
Nagapatam	36	1484·40	989·60	88·32	5·95	7·9	1480·56
Pattukottai	36	1078·00	718·67	126·77	11·76	4·9	960·00
Mannargudi	36	1409·11	939·41	83·56	5·93	*	*
Aranthangi	36	1122·97	748·65	113·76	10·13	6·1	1037·04
Thiruthuraipoondi	35	1044·04	696·03	118·39	11·34	6·6	1280·56
Total district	395	1361·67	907·46	34·33	2·51	7·1	1279·79

* Estimates are not reported

n examination of the table shows that the aver- yield in seven out of the eleven *talukas* has been mated with precision approaching five per cent pling error. For the district as a whole, the rage yield is determined within a margin of per cent error. The *taluka* estimates are given y to show the evidence on which the district mate is based and are not meant to be used with same confidence as the district estimate. The d per acre varies from 1,044 lb. in the Thiru- raipoondi *taluka* to 1,555 in Nannilam. The yield in the former is due to the fact that unlike he other *talukas* $\frac{1}{3}$ of the area in the *taluka* is rrigated. The estimate for the district as a ble works out at 1,351 lb. of dry paddy and 901 of rice per acre. A clear idea of the variation in d is obtained from the frequency distribution of t yields given in Table II which shows that yield of paddy varies from 0 up to 3,069 lb. acre.

A comparison of the sample estimates and the cial figures is not possible since the latter includes the crops including the Kuruvai crop which was luded from this survey. No figures for the official mates of acreage under paddy and of the yield acre are therefore given.

One of the objects of the survey was to estimate possibility of the method of eye-estimation on dom fields for forecasting the probable size of crop before harvest. Accordingly the field staff e asked to report eye-estimate in annas and in nds per acre of the standing crop in the fields eted for the survey.

The averages of these estimates for each *taluka* are n in the last two columns of Table I. A com- ison of the eye-estimate in pounds per acre with sample estimate derived from the results of the p-cutting experiments shows that the eye- imate as a rule is lower. For the district as a ole, the eye-estimate is lower by 15·4 per cent.

The average of the anna estimates for a *taluka* ies from 4·9 to 8·5 and works out at 7·1 for the trict. As 12 annas represent the normal yield 1,750 lb., the estimate of 7·1 annas for the dis- t is equivalent to 1,035 lb. of dried paddy. This considerably lower than either the eye or the mple estimate based on the results of crop-cutting periments. This difference was expected, for, to reporting authorities normal represents a crop proaching a full crop, and consequently the anna imate refers to what is to all purposes a full crop l not the average crop on average soil in a year average character. This is also borne out by the t that the average of the anna estimates over a ies of years is found to be lower than the anna ivalent of the normal figure, viz. 12. This in t is the basis underlying the application of Ste- rt's correction factor for the pessimism of the reporting authorities adopted in Madras. This cor- rection factor for the District Tanjore is 100/75. Applying this correction factor to the anna estimate, the revised anna estimate comes to 9·4 annas. On the basis of the revised anna estimate the yield of paddy in lb. per acre for the district works out at 1,371 lb. which compares not unfavourably with the eye or the sample estimate.

The yield per acre derived from the results of crop-cutting experiments relates to the area sown with paddy excluding the area covered by the field boundaries. As against this, the official figures of acreage include the area covered by the field boundaries. An estimate of the proportion of the area covered by these boundaries is thus needed, lest a straightforward product of the yield per acre with the reported figure for the acreage may give an overestimate of the total outturn. A rough estimate of this proportion is obtained from the data relating to the length and breadth of the fields reported in Form 1. These results show that the average length and breadth of a field are approximately 194 ft. and 114 ft. Working on the basis of 2 ft. width, this gives an estimate of 2 per cent for the area occupied by field boundaries, which is to be deducted either from the estimate of the yield per acre or from the reported acreage before obtaining an estimate of the total outturn.

TABLE II

(Tanjore District, 1944-45)

Frequency distribution of plot yields of paddy

Limits in lb. per acre	No. of plots	Percentage on total
200	11	2·04
400	9	2·30
600	13	3·32
800	21	5·36
1000	33	8·42
1200	41	10·46
1400	45	11·48
1600	50	12·76
1800	39	9·95
2000	41	10·46
2200	42	10·71
2400	26	6·63
2600	12	3·06
2800—	9	2·95
3000	1	0·26
3200	2	0·51

Equally, it has been noticed that small losses occur during the process of harvesting, threshing and winnowing, e.g. a little grain is found to go with the straw despite the care taken by the staff. There is no means of estimating the loss on these

heads but all the reports go to confirm that the loss was negligible. These losses and any slight bias that may result from sampling processes to which a reference is made later, are best combined with the more important losses such as those on driage into an overall correction factor which can be applied for estimating the final yields.

Table III shows the results of the analysis of variance of plot yields in each of the different *talukas*. The Analysis of variance pooled over the district is shown at the bottom of the table. The Chi Square test of significance shows that there is no evidence to suggest that the mean squares between villages in the different *talukas* are different and indicates that the sampling variance of the district estimate of mean yield can properly be calculated from the pooled analysis of variance for the district. This procedure has accordingly been followed in calculating the standard error of the district estimate of the average yield.

When the number of fields sampled from each village is constant, then the sampling error of the *taluka* and district estimate of mean yield are directly obtained from the mean square between villages in the analysis of variance table. Usually, on account of some reason or other, the number of fields is unequal. In the present case, there is one village in Thiruthuraipoondi *taluka* where only two experiments were conducted. In such a case, as pointed out by Cochran [1939] it is necessary to estimate the true values of the variance between villages and between fields within villages. In other words, we must know the estimates of the variance between villages when all the fields in the selected villages are sampled. If we denote the true variance between and within villages for the *i th taluka* by *Vi*

TABLE III

(Tanjore, 1944-45)

Analysis of variance of plot yields

Name of *Taluka*	Sources of variations	d.f.	S.S.	M.S.	Estimated true variance
Tanjore	Between villages	11	9011600·83	819236·44	225248·78
	Within villages	24	3443761·67	143490·07	
Kumbakonam	Between villages	11	3084373·72	280397·61	13103·77
	Within villages	24	5786071·33	241086·31	
Papanasam	Between villages	11	2267539·89	206139·99	36884·81
	Within villages	24	2295253·33	95635·56	
Mayavaram	Between villages	11	2302102·39	209282·04	11680·69
	Within villages	24	4181759·33	174239·97	
Shiyali	Between villages	11	3279912·91	298173·90	12774·29
	Within villages	24	6236424·50	259851·02	
Nannilam	Between villages	11	1896353·72	172395·79	
	Within villages	24	4454088·83	185612·03	—
Negapatam	Between villages	11	2354494·75	214044·98	13876·13
	Within villages	24	4137998·00	172416·58	
Mannargudi	Between villages	11	2113822·67	192165·70	14968·83
	Within villages	24	3534220·83	147259·20	
Aranthangi	Between villages	11	3910259 41	355478·13	55048·32
	Within villages	24	4567996·33	190333·18	
Pattukottai	Between villages	11	4861170·58	441924·60	81950·58
	Within villages	24	4705748 17	196072·84	
Thirthuraipoondi	Between villages	11	4121057·61	374641·60	81692·46
	Within villages	23	3141027·33	136566·41	
Total district	Between *talukas*	10	11916799·80	1191679·98	
	Between villages	121	39202688·84	323989·16	49080·10
	Within villages	263	46484949·66	176748·85	

Fi respectively, then it can readily be shown
t the estimates of *Vi* and *Fi* for the *taluka* are
ained by equating the mean squares between
ages and between fields within villages in the
lysis of variance with

$$\frac{V_i}{m_i - 1}\left\{N_i - \frac{\Sigma n_{ij}^2}{Ni}\right\} + Fi \text{ and } Fi$$

ere

Nij = the number of fields in the i *th* village;
N_i = " " *taluka*;
m_i = " villages in the *taluka*.

ese estimates of *Vi* and *Fi* for each *taluka* of the
trict are given in the last column of Table III.
ven these, it can be shown that the sampling vari-
e of the *taluka* mean yield $\overline{X}_i$ is given by

$$\frac{V_i \, \Sigma n^2_{ij}}{N_i^2} + \frac{Fi}{Ni} \quad \text{and}$$

t of the district mean yield $x = \frac{\Sigma \overline{xi}}{t}$ by

$$\left\{V \Sigma\left(\frac{\Sigma n^2_{ij}}{N_i^2}\right) + F \Sigma\left(\frac{1}{N_i}\right)\right\}\frac{1}{t^2}$$

ere t is the number of *talukas* and V and F refer
the estimates of the true variance for the district.
hen the number of fields in each village is the
ne, the sampling variance of the *taluka* mean yield
uces to $\frac{V}{m_i} + \frac{F}{m_i n}$ and that of the dis-
t mean yield to $\frac{V}{m} + \frac{F}{mn}$ where m is the
mber of villages in the district. This is identical
h the mean square between villages in the ana-
is of variance table divided by the total number
experiments. The standard errors of the *taluka*
d district mean yields shown in Table I were
culated by the above formulae.

Turning to Table III, it will be seen that the mean
uare between villages is larger than the mean square
tween fields within villages in all *talukas* except
e, and that in three *talukas* the difference is signi-
ant. The district analysis shows that the former
nearly twice the latter. This comparison does
t, however, bring out the true relation between
e variability between and within villages; for,
e mean square between villages in the analysis of
riance table includes the variation in sampling
tween fields within villages. The true relation
tween the variability between and within villages
given by a comparison of V and F shown in the
st two columns of the table. Such a comparison
ows that field to field variation is the more pre-
dominant source of variation, being on the average nearly three times in magnitude as compared with the village to village variation. The same conclusion has been reached in the Punjab Survey as also in the Cotton Survey conducted by Panse and Kalamkar [1944]. These results have an important bearing in determining the number of experiments and their distribution as between villages and fields in a village for estimating the district mean yield with a given degree of accuracy. This is explained below.

It will be seen from the formulae for the sampling variance of the district mean yield that for a given number of experiments the estimate of mean yield attains a maximum precision when the number of experiments are so distributed that one experiment each is conducted in a different village of the district. The precision of the district estimate of mean yield falls off when the number of experiments per village is increased at the expense of the number of villages in the district. This will be clear from Table IV showing the number of villages that must be sampled for a given number of fields per village and for one plot per field in order to estimate the district mean yield with a given accuracy. It will be seen that there is a considerable advantage in increasing the number of fields from 1 to 2, but the advantage is rapidly lost with further increase in the number of fields. Thus, whereas the number of villages required for obtaining an estimate with 5 per cent error decreases by 25 when the number of fields is increased from 1 to 2, the number of villages required decreases by only 8 when the number of fields is increased from 2 to 3. There is hardly any material difference in the number of villages that must be taken when the number of fields is increased from 3 to 4 and more. The number of villages shown in the table refers to the whole of the district and is to be distributed among the different *talukas* in proportion to the area under paddy. It is subject to sampling errors since the values of V and F are themselves only sample estimates of the population values. These errors are shown with a plus and minus sign in the table.

There are, however, considerations other than the precision of the yield estimate on which depends the number of experiments to be conducted and its distribution as between villages and fields within a village. These are (*a*) the staff available for work in each *taluka*, and (*b*) the limited time available for harvesting. Where only one worker is available in a *taluka*, it is not possible to adopt the ideal plan of conducting one experiment each in a different village of the *taluka*, for it is hardly possible for the persons concerned to visit all the villages in his jurisdiction within the time available for harvesting. Under the conditions existing today, it takes on an average a day to travel from one

TABLE IV

(Tanjore district, 1944-45)

Number of fields per village	Number of villages required for different percentages of standard errors		
	5 per cent	7·5 per cent	10 per cent
1	61	27	15
2	36	16	9
3	28	12	7
4	24	11	6
5	21	9	5
6	20	9	5

random village to another in a *taluka*. This naturally puts an upper limit to the number of villages that can be managed by the staff concerned during the time at his disposal, and councels us to utilize the available time of the worker to the maximum advantage. One experiment per village does not provide the worker with sufficient work on reaching a village ; nor is the work of a nature that he can finish it within an hour or two and return to another village. For, a worker has to wait for a few hours after the crop is harvested in order that it may be in a condition fit for threshing. On the other hand, this time can be usefully spent in harvesting additional experiments in the same village. The consideration of thus spreading the number of experiments over as large a number of villages as possible and yet of using the available time of the worker, particularly that between the operations of harvesting and threshing, to the maximum advantage, as also the consideration that the true variability from field to field is pronounced, suggest a scheme of work which councels more than one experiment per village. In a previous paragraph we have seen that there is an advantage in increasing the number of fields up to three per village, which is just the number which experience shows can be entrusted to a worker during the course of the day.

Previous work [Panse and Kalamkar, 1944] has indicated that the mean yield differs significantly among the *talukas*. In selecting random sample of villages for the district a separate random sample was therefore taken in each *taluka* and not a single sample over the entire district. This was done with a view to eliminate the differences in yield between *talukas* from the sampling error of the mean yield for the district. The advantage of this procedure will be obvious from the analysis of variance shown at the bottom of Table III. The table shows that the mean square between *talukas* is significantly larger than the mean square between villages. The gain in precision obtained from this procedure of stratification is easily evaluated by recalculating the analysis of variance table in which the sums of squares due to *talukas* and due to villages are summed up and divided by the combined degrees of freedom. The quotient of the mean square thus derived by the mean square between villages in the original analysis of variance table less one gives the gain in precision. In the present case the calculation shows that stratification by *talukas* improved the precision of the district estimate by 18 per cent.

Table V shows the values of the coefficient of variation for the three different sizes of plot, viz. 1/120th, 1/60th and 1/40th of an acre for each of the *talukas* and for the district as a whole. The table shows that the coefficient of variation decreases gradually as the size of plot increases, but the rate of decrease is very small and suggests that the variation in plot size within the range 1/120th to 1/40th of an acre has little effect on the accuracy of the mean yield. It is probable that even a smaller plot size than 1/120th of an acre may not greatly influence the accuracy of the mean yield.

TABLE V

(Tanjore, 1944-45)

Coefficients of variation for different plot sizes

Name of the *taluka*	1/120th of an acre	1/60th of an acre	1/40th of an acre
Tanjore	16·38	14·66	13·11
Kumbakonam	10·53	7·92	6·64
Papanasam	15·87	15·36	17·05
Mayavaram	7·82	9·89	6·11
Shiyali	7·49	6·58	9·71
Nannilam	9·44	8·86	7·68
Negapatam	10·42	8·33	7·29
Mannargudi	14·17	12·98	7·25
Pattukottai	18·58	16·69	15·48
Aranthangi	16·48	13·11	11·80
Thiruthuraipoondi	12·18	10·41	8·63
Whole district	12·76	11·58	10·61

There is, however, an inherent difficulty in sampling from a finite field. Whatever the size of plot, the central portion of the field is relatively over-sampled when compared with the wide surrounding area. Consequently there is a likelihood of obtaining a biased estimate of the mean yield if the yield of plots located near the borders is different from that of plots in the remaining part of the field. As the bias in sampling diminishes with the size of plot, some workers believe that the remedy lies in reducing the size of plot. It is however clear that the bias in sampling cannot be removed by this means. One method of removing the bias will be to select a pair of numbers at random from the sets *0, a, 2a,* .... and *0, b, 2b,*..... where *a* and *b* represent the length and breadth of the plot provided the

ength and breadth of the field are integral multiples of a and b. Another remedy lies in introducing a correction factor such that it will equalize the chance for every portion of the field being included in the sample. If p is the probability that a sample plot occupies in a particular portion of the field and q the probability of equal chance for all portions of the field, then the proper allowance for the inequality in chance is the weighted average of plot yields, in which a plot yield has a weight q/p. If L denotes the length of the field and B its breadth, a the length of the plot and b its breadth, (r, s) the pair of random numbers denoting the starting point of the plot, then it has been shown elsewhere by the author [1945] that q/p is given by:

$$\frac{a^2 b^2 (m+1)(n+1)}{LB\left[a^2 - \frac{\alpha(\alpha-1)}{2} - \frac{\beta(\beta-1)}{2}\right]\left[b^2 - \frac{\alpha^1(\alpha^1-1)}{2} - \frac{\beta^1(\beta^1-1)}{2}\right]}$$

where $\alpha = a-r$ if α is +ve, $\beta = a+r-m$ if β is +ve
$= o$ otherwise, $= o$ otherwise
$\alpha^1 = b-s$ if α^1 is +ve, $\beta^1 = b+s-n$ if β^1 is +ve
$= o$ otherwise, $= o$ otherwise
$m = L-a$ and $n = B-b$, a and b, being integers

TABLE VI

(Tanjore District, 1944-45)

Average yield corrected for bias resulting from over-sampling the centre of the field

Name of *Taluka*	Average yield of paddy in lb. per acre	Average yield corrected for bias in lb. per acre
Tanjore	1446·04	1500·87
Kumbakonam	1439·89	1513·79
Papanasam	1667·71	1697·22
Mayavaram	1695·97	1696·27
Shivali	1688·56	1652·91
Nannilam	1697·92	1719·30
Negapatam	1620·52	1490·36
Mannargudi	1538·33	1541·49
Aranthangi	1225·95	1218·99
Pattukottai	1176·86	1219·52
Thiruthuraipoondi	1139·78	1149·32
Total district	1475·09	1486·22

The results of the application of this correction factor are shown in Table VI. In this table column 1 shows the name of the *taluka*, column 2 shows the average yield of paddy in pounds per acre uncorrected for the sampling bias, and column 3 shows the estimate of the average yield corrected for the sampling bias. It will be seen that the difference between the original estimate and the one corrected for the position bias is negligible compared with the sampling error of the average estimated yield. For the district as a whole, the difference is altogether negligible. It would appear that no correction is necessary in practice.

TABLE VII

(Tanjore District, 1944-45)

Average yield of plots in relation to its position in the field

Length			Breadth		
Relative position of the plots.	No. of plots	Average yield	Relative position of the plots.	No. of plots	Average yield
·00—·1	25	1238·9	·00—·1	42	1029·0
·1—·2	35	1119·6	·1—·2	45	1107·8
·2—·3	56	1219·5	·2—·3	53	1211·8
·3—·4	38	1143·21	·3—·4	51	1262·4
·4—·5	47	1241·00	·4—·5	43	1288·9
·5—·6	45	1134·0	·5—·6	33	1129·6
·6—·7	36	1320·5	·6—·7	31	1162·6
·7—·8	38	1108·3	·7—·8	36	1236·1
·8—·9	33	1220·2	·8—·9	39	1177·8
·9—1·0	39	1116·6	·9—1·0	19	1294·7

The influence of sampling bias has also been examined by calculating the frequency distribution of plot yields according to the relative position of plots in the field. The results are shown in Table VII. The relative position of the plot defined by the quotient of the random number of the starting point of the plot by the length of the field less the length of the plot is given in column 1. The number of plots having the relative position defined in column 1 is shown in column 2, and the average yield per plot is given in column 3. Columns 4, 5 and 6 give the same figures when the relative position is defined along the breadth of the field. The χ^2 test of significance for the number of plots in the different class intervals shows that the location of the starting point of the plot was genuinely random, as was to be expected. A comparison of the variation in yield within classes with the variation between classes shows that the yield per acre is not influenced by the relative position of the plot in the field.

Practical considerations are no less important than theoretical ones in determining the size of

plot. Of these considerations perhaps the most important is the simplicity of procedure. This can be ensured by making only the minimum essential changes in the present procedure of conducting crop-cutting experiments. This is most important in securing the co-operation and confidence of the administrative officers and cultivators. Departmental crop-cutting experiments in Madras are done on a plot size of 20 links $\times$ 50 links (1/100th acre) and it would appear that this plot size may be continued pending further investigations.

The next practical consideration is the need for ensuring that the error in the location and marking of plots is minimized and that no losses occur in the process of harvesting, threshing, winnowing and weighing. Experience shows that in the unevenly sown crops in India, the use of very small plots leads to large errors in their marking by the tendency to include the border plants within the plot. When the plot size is small, the number of bunches on the border forms an appreciable proportion of the total number of bunches inside the plot, and the base of the bunch being fairly large, a personal factor is brought in in deciding whether to include the border bunches inside the plot, to exclude them or to divide them. The tendency appears to be to include more number of plants than what properly belongs to the plot. The results of investigations on the comparison of small versus large-size plot, conducted in the Punjab and the United Provinces show that the use of very small plots such as are marked by a rigid or semi-rigid frame in the hands of the existing staff leads to overestimation of the yield, but that the bias diminishes with the increase in the size of the plot. Similar considerations apply to the losses that occur during the processes of harvesting, threshing, winnowing and weighing of the produce. Unless the staff is well-trained and arrangements are made for processing the produce at a central place, there is a risk in handling small produce under the conditions obtaining in the villages. For, the produce is handled and processed by village labour who do not realize the importance of accurate operations. A large plot size of the order of 1/100th of an acre is mostly free from these limitations.

A third consideration determining the size of plot is the necessity of ensuring that fields which are too small to contain the plot form a negligible proportion of the total number of fields. The percentage of fields rejected in the present scheme, where a plot size 1/20th of an acre was used, is less than 2 per cent. The frequency distributions of length and breadth of the selected fields show that there is no risk whatsoever of rejecting any fields in using a plot size of 1/100th of an acre, and therefore no need to change the existing one-cent plot size.

To sum up, it would appear that on both theoretical and practical grounds, a large plot size is better than a small plot size such as is marked by a rigid or semi-rigid frame (area : approximately 10 or 20 sq. ft.) under the conditions obtaining in this country. Within the range of small size plots, however, it may be feasible to take a plot of smaller dimensions consistent with the requirement that errors due to the measurement of the plot and processing of the produce do not contribute more than a negligible proportion of the produce harvested. All the available evidence go to suggest that there is no particular advantage in reducing the existing one-cent size plot used in official experiments, and indeed there is a definite risk of obtaining a biased yield estimate in asking the field staff to experiment with frames.

Random sampling implies equal chance for every plot in a *taluka* to be included in the sample. This can be done by considering the whole of the area of the *taluka* divided into plots and selecting random sample from these plots. This, however, is not a feasible method. The practicable method of selecting a random sample of plots is to select a random sample of fields and locating sample plots in each of these selected fields. The easiest way of selecting a random sample of fields is to select random groups of fields and then to select fields at random from each of these groups. The best group is the one for which the list of fields is readily available and in which the fields are readily located with the help of the local officials. The investigations of Panse and Kalamkar [1944, 1 and 2] in India show that there is no difficulty in selecting villages at random, nor is there any difficulty in selecting fields at random from each of the selected villages. In this method, however, every unit area does not get an equal chance of selection. Smaller villages and smaller fields get relatively larger chance of selection. This requires correction, particularly if there is an association between the area and the yield. One method of correcting is by forming progressive totals of areas and of fields in selected villages before a selection is made. Another method would be to work out weighted averages by weighting the yield of each plot with the area of the corresponding plot and weighting the average yield of a village with the corresponding area under paddy. These weighted averages have been calculated and show that these sources of bias in sampling have no effect on the estimated yield. It appears that no correction would be necessary in practice.

It will be recalled that in Tanjore *Taluka* a special enquiry was undertaken for investigating the possibility of using a paddy-growing field itself as the ultimate unit of sampling. The results of this enquiry are given in Table VIII. It will be seen that the average yield in lb. per acre from

his enquiry comes to 1447 as against 1446 which the average estimated from harvesting 1/20th of n acre plots from the same fields. In working out ne analysis of variance the yields reported were onverted to per acre basis. The results are similar o those shown in Table III. The estimate of the ercentage of grain going along with the straw omes to 10·85 and shows that it is likely hat considerable grain may normally be expected o go with the straw unless care is taken to separate ll the grain from the straw.

TABLE VIII

(Tanjore District, 1944-45, Tanjore *Taluka*)

verage yield of paddy in lb. per acre			1447
Analysis of variance		*S.S.*	*M.S.*
etween villages	11	9907515·64	900683·24
ithin villages	24	7539908·33	314162·85
tandard error	158 lb. per acre		
ercentage standard error	12		
ercentage of grain going with the straw			10·9

The result that the estimate of yield from 1/20th f an acre plots is not different from that derived y harvesting the whole of the field is of importance, or it shows that a large plot gives an unbiased esti- ate of the yield per acre. On grounds of preci- on also there is not much advantage in using a eld as the unit of sampling in place of 1/20th of n acre plots. There are, however, a few practical nsiderations in favour of field as the unit. In he first instance, no trampling is involved either in he process of marking or harvesting and secondly, he co-operation of the cultivator is easily secured nasmuch as the whole of the field is harvested t Government cost. The question of errors in the arking and measurement of plots also does not rise. As against these considerations, more labour nd more money are needed for harvesting the elds. Tanjore fields are somewhat large in size, ut in other rice tracts, it is possible that the use f a field in place of a plot of a given size may prove ore efficient.

Although the primary purpose of the survey was o determine the sampling technique, the data ollected can also be used for estimating the extent f cultivation practices. Thus the results show that f the total area under the Samba crop and the econd crop, over 80 per cent is under Samba and hat the second crop consists mainly of Ottadan, he percentage estimates of the area under Ottadan nd the Samba Double being approximately 10 and 5 respectively. Information in respect of manuring shows that paddy, as a rule, is extensively manured in Tanjore, the percentage area manured being 70. The main manure used is farm-yard manure, but ammonium sulphate is also used.

The advantages of the random sampling method of conducting crop-cutting experiments are that the estimate of yield is unbiased, its precision is known, and that the true fluctuations in the outturn from year to year are clearly brought out. These advantages have been known to all concerned for a long time, but as has been pointed out in a previous paper [Sukhatme, 1945], the administrators thought that the method of random sampling was difficult of adoption in practice and that heavy additional expenditure would be necessary. Nevertheless, Madras has been the first province in India to adopt random sampling method for conducting crop-cutting experiments. Under this procedure, a large number of villages are selected at random, larger than what is required for estimating the district yields with 5 per cent accuracy. Experiments are not, however, carried out in all the selected villages, and it is probable that they are carried out in only those of the selected villages which are easily approachable. Fields are also randomly selected, but the number of experiments conducted in the different villages is unequal. There is, in fact, no principle governing the total number of experiments to be conducted or its distribution as between villages and fields in the selected village. Plots are not located at random but near the centre of the field. The results of this survey show that a slight modification of the existing procedure will not only result in a less number of experiments but give an unbiased estimate of yield. The results further show that the work can be carried out by the existing departmental staff as part of their normal duties without heavy additional expenditure. The work will naturally require strong statistical direction for planning, for analysing the results, for incorporating them in successive years plans and for guarding against the possibility of the random sampling method degenerating into inefficient routine by ensuring adequate supervision of field work. It is to be hoped that Madras will modify their official procedure to the extent indicated in the report and continue to carry them out on a permanent basis on the modified lines.

SUMMARY

The paper describes the results of a crop-cutting experimental survey on rice carried out in Tanjore District. The plan adopted for the survey was the stratified plan of random sampling. A total of 132 villages was selected from the district. These were divided equally between the 11 *talukas*. Within each village three fields were selected and

within each field a plot 1/20th acre was harvested. The plot was further divided along the length into six equal strips, 11′×33′ each. In one *taluka* in addition to the plot the whole of the remaining field was also harvested. For the District as a whole the estimated average yield came to 901 lb. of rice per acre. The sampling error of the estimate was less than 2½ per cent.

On the technical side the results show that a scheme of sampling involving a selection of about 30 villages in a district, distributed approximately in proportion to the area under paddy in the different *talukas*, with three fields in each *taluka* and one plot of 1/100th acre in each field, is expected to give district estimate of the average yield with sampling error approaching 5 per cent. On the question of plot size the results show that there is no advantage in reducing the existing one-cent plot used in official experiments.

The advantages of the random sampling method of conducting experiments have been emphasised and it is shown that a slight modification of the existing official procedure will not only result in a less number of experiments but give an unbiased estimate of the average yield.

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EXPERIMENTS ON THE CONTROL OF FLY-BREEDING IN COMPOST TRENCHES *

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(With two text-figures)

PREVENTION of fly-breeding is an essential requirement of any satisfactory system of compost-making, especially while dealing with town wastes such as night-soil and *katchra* (dry refuse), which come to the Compost Depot previously infested with fly eggs and larvae. Flies are known to be common carriers of disease organisms such as *B. coli*, *Bacillus dysentericus*, ascaris (hook-worm), the germs of typhoid, cholera, tuberculosis, anthrax, etc. The house fly (*Musca domestica*) is in this respect the worst offender; and in places where the Compost Depot is situated quite adjacent to inhabited localities, disease may be transmitted from the Depot to the town by flies. During the development of the Bangalore Process of composting town wastes and its introduction into different municipal centres in this country [Acharya, 1945], a great amount of attention was paid to evolving a simple technique which would satisfactorily prevent the development and escape of flies from compost trenches. Special attention was paid to the house fly (*Musca domestica*) in the above connection.

Infection may be transmitted from compost trenches in either of the two ways, viz. (*a*) fly eggs and larvae may be already present in the night-soil and refuse (*katchra*) when these arrive at the Depot; and after being loaded into trenches these may become flies and carry infection to the town: this type of breeding may be termed 'internal' for convenience of reference, and (*b*) after the trench is filled up, extraneous flies at the Depot may deposit eggs in the refuse and these eggs may develop into flies and carry infection from the trench; this type of breeding, may be termed 'external' in contrast to group (*a*).

In any satisfactory system of compost-making, it is necessary that both the above types of fly-breeding—'internal' and 'external'—should be properly controlled and eliminated. In the Bangalore Process, the 'external' infection (group *b* above) is eliminated by covering the compost mass (in the trench) with a two-inch layer of dry earth, which

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factorily covers all the organic debris and offers a clean earth-layer, which does not attract to oviposit. The problem of control of group viz. internal infection, was however found to ore difficult and more complicated. The object e investigations reported in this paper was to re a cheap and simple method of control which l be adopted by municipalities for eliminating 'internal' breeding, i.e. the emergence of flies fly eggs and maggots already contained in the -soil and *katchra*.

e magnitude of this problem is evident from the that in certain municipalities where the night- s collected during the day and stored overnight arts in the town before being removed to the ost Depot next morning, there is often heavy tation with fly larvae, running to the order veral thousands per lb. of excreta. The count v eggs is probably much greater. When one ders that the average excretion of night-soil out ½ lb. per head per day, the intensity of fly- nce that may be created per head of urban lation by the presence of a badly managed se Disposal Depot near about is evident.

e degree of fly infestation that refuse (*katchra*) s varies with the locality and also with the n, the worst periods being the rainy and cooler ns, especially in areas where the rains are mittent and temperatures are not very low.

Existing methods of fly control

study of the fairly extensive literature on fly ol shows that the methods adopted by workers is field may be broadly classified under three s as indicated below.

(A) *Mechanical and chemical methods*

se methods make use of maggot traps [Baber, Cragg, 1920] of fly traps with sugar baits ed with chemicals such as formaldehyde, m salicylate or sodium fluoride [Phelps and nson, 1916; Shaffi, 1936; Deoras and Jandu,] or poisonous sprays like pyrethrum, derris or ine [Lefroy, 1919; Twinn and Herman, 1928; obell, Sullivan and Jones, 1934; Richardson, , arsenite or arsenious acid [Lefroy, 1916; son and Richardson, 1933], creosote oil or tar Foreman and Graham Smith, 1917; Kearns, or other chemicals such as borax, hellebore, [Cory, Harns and Anderson, 1936; Fenton Bieberdorf, 1936].

(B) *Biological methods of control*

ese methods use adult and larval parasites as the fungus *Empusa muscae* Cohn [Gussow, predators such as beetles [Lever, 1938; Sim- is, 1940], ants [Simmonds, 1925] or poultry band, 1921]. These, however, have not been ssfully developed and the results obtained have been satisfactory.

(C) *Thermal and electrical methods*

Electrified screens have been utilized for electrocutting the liberated flies when they attempt to get out [Wells, 1931]. Incineration of refuse or burning the top layer of refuse with the Blow Torch Primus stove produces a similar result.

It was found, however, that none of the above methods was suited for routine adoption on Compost Depots operating under Indian conditions, for the reasons that (*a*) either the destruction of flies was only partial as in the use of fly-papers and fly-traps, or (*b*) the method involved the use of costly chemicals or costly equipment which rendered the operation uneconomical. Since the compost was to be used as agricultural manure, the use of large quantities of poisons such as arsenic, cyanide and tar products was evidently undesirable; and, moreover, their use by unskilled sweeper-labour under routine Depot conditions was likely to leave room for misapplication and thus constitute a danger to life.

Four methods which appeared to suit Compost Depot conditions in India and which were taken up for more intensive study were (*a*) the Indore Process for fly control in compost [Howard and Wad, 1931], (*b*) Fay's system [1936], (*c*) Burning a layer of dry refuse on top of the earth-cover in the trenches, suggested by Mr M. A. Idnani (unpublished communication), and (*d*) Isaac's triple earth plaster system [1944].

Trials of the above methods were carried out after adding to the compost an inoculum containing a known count of the larvae of the house fly (*Musca domestica*). Various preliminary studies were also carried out in order to follow the life-cycle of the house fly and to study physiological factors affecting its development.

Preliminary experiments

It is unnecessary to present here the data obtained in the preliminary trials but they led to the following conclusions:

(i) When a known number of fly larvae were added to the compost mass on the day when the compost was made, about 50-75 per cent of the total number were destroyed by the heat which rapidly developed in the fermenting mass and about 25 to 50 per cent of the total number emerged as flies. The percentage emergence depended on temperature and humidity conditions, being lower in the hot dry periods of February to June and higher in the rainy and cooler season of July to January. In the former period, the compost mass reached rapidly high temperatures of over 65°C., whereas in the rainy season, the compost mass became waterlogged and the temperature levels were much lower (45°C.—50°C.). The percentage of fly emergence was found to be great also in cases where the proportion of *katchra* (refuse) to night-soil used in

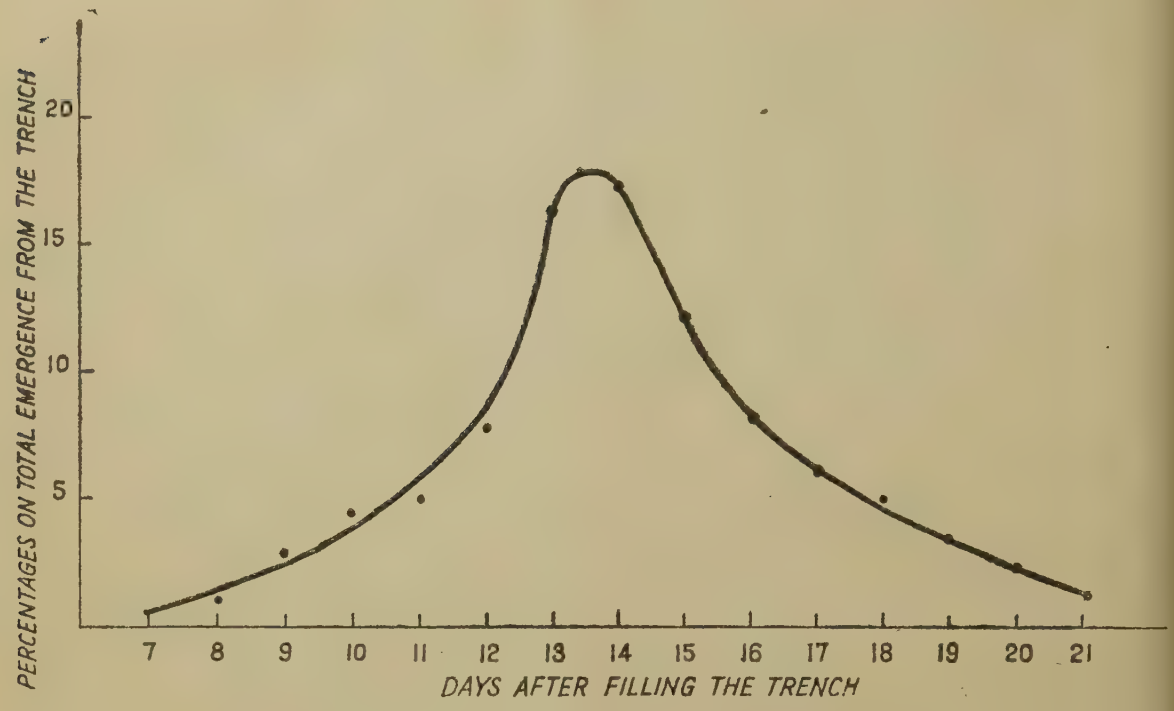

FIG. 1. Daily emergence of flies from a compost trench

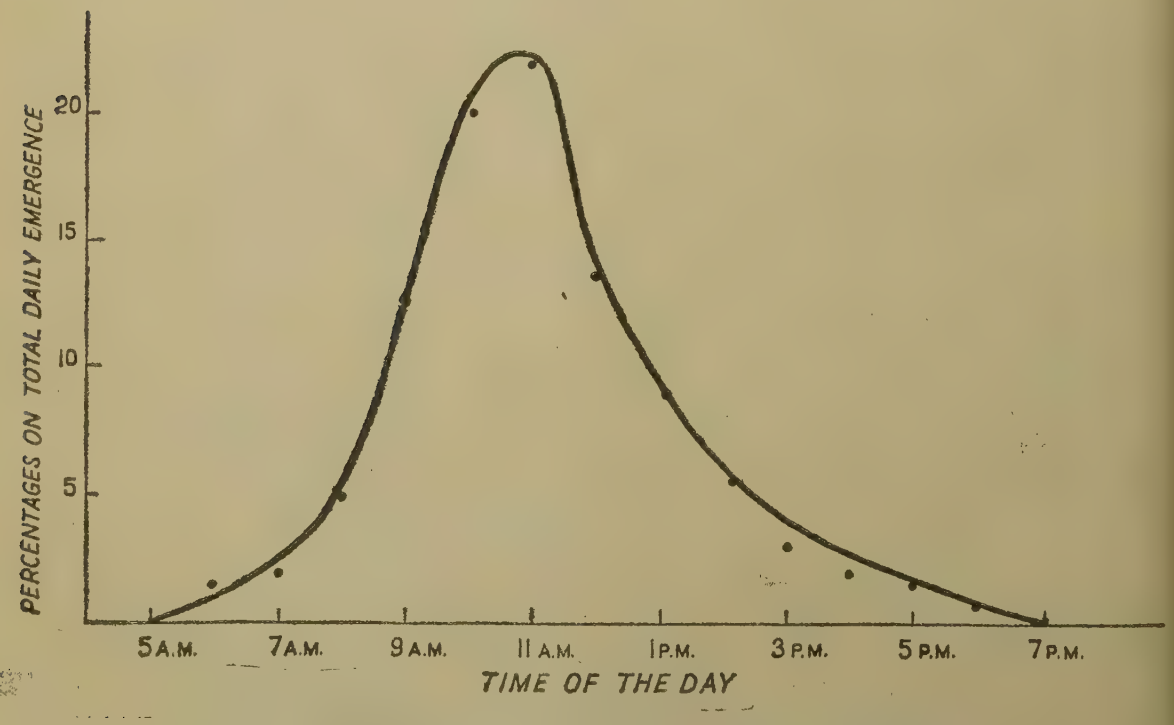

FIG. 2. Emergence of flies from a compost trench at different hours of the day

ıpost-making was less than one part by weight *katchra* (or three parts by volume) to one part night-soil. Where *katchra* was deficient, enough t was not produced in the compost mass and fly elopment was excessive.

ii) The rates of daily emergence of flies from the ıpost mass fitted in with the normal population ve, as shown by Fig. 1. The emergence of flies erally started on the 8th or 9th day after the was filled, reached a peak on the 14th or 15th and came down to a stop about the 20th or 21st from the initial filling of the pit. It therefore ned suitable to apply fly control measures to the on the 6th or 7th day after the pit was filled. e period 7th to 14th day appeared to be the most ical period in the cycle of fly emergence.

iii) A study of the hourly variations (Fig. 2) in number of flies emerging during the day, showed t there was practically no emergence of flies from manure during the night. Fly emergence started r sunrise, generally between 7 a.m. and 8 a.m. pending on the season) and reached a peak bet- n 10 a.m. and 11 a.m. (depending again on the son and atmospheric temperatures) and rapidly ıe down after 1 p.m. By about 3 p.m. over 95 cent of the day's emergence had taken place. ıce it would appear that for purpose of taking y fly counts, 5 p.m. would be a suitable hour.

ıv) In the Indore Process, three turnings are ommended, viz. on the 5th, 12th and 20th days r the heap is made. The instructions are that top layers of the heap should be turned down orm the inner core of the new heap at each ing. It was found that (*a*) in addition to extra ur charges involved, the turnings had to be n under very careful and responsible supervi- : and the sweeper-labour employed at municipal ts for compost-making could not be expected arry out the work properly; (*b*) in the case of e masses, careful turnings became more difficult; (*c*) in the absence of proper turnings, a good portion of the larvae managed to escape to the er top and side layers of the compost, and fly rgence became high (30-40 per cent of the l inoculum count). Since, in the Bangalore ess, mixings and turnings of the compost mass avoided in order to bring down labour charges, her examination of the Indore system was ped and attention was concentrated on the aining three methods, viz. Fay's, Isaac's and ani's.

saac [1944] recommended placing on top of the ure heap three alternate layers of earth, each r being 4 in. thick, of which one half thickness puddled with water and the other half was dry. In addition to the heavy labour charges lved in preparing and applying three alternate rs of earth plaster, the method involved the use of such large quantities of earth (1 ft. thickness) that it would prove unworkable on a routine basis on most municipal Compost Depots. Further, the heavy layer of earth would tend to make conditions quite anaerobic inside the trench and thus would delay decomposition and maturation of the manure by more than a year.

Fay's [1936] method depends on the thermal destruction of fly-larvae, by the greater heat produced in the compost mass by covering it with tar-coated burlap cloth. He tried his method mainly on overground heaps and covered the top and partially the sides, with tarred paper or cloth, and found that a large number of the fly maggots climbed down to the foot of the heap and pupated in the ground below. In order to avoid such pupation, he recommended digging a drain all round the bottom edges of the heap and filling the drain with water (mixed with an insect poison), so that the larvae may get sunk in the water and may be destroyed. He found that the temperatures below the black paper or burlap were about 30°F. to 40°F. higher than the atmospheric temperature, and that when the latter was above 80°F. for 5 hours in the day, enough heat was produced below the black cover to destroy the fly larvae and pupae. The weak point in Fay's method is the scope left for the fly larvae to escape from the bottom of the heap, and the need for cutting a drain all round the heap and keeping it always filled with water. Such an arrangement involves costly equipment which would prove to be economically unworkable on most municipal Compost Depots in India.

Investigations were therefore directed towards evolving a method or methods, which would secure fly destruction of the order of over 95 per cent in one simple operation and which would involve an extra cost of a few annas only per ton of compost manure produced.

Jar experiments

A set of trials was carried out in glass jars 6 in. breadth, 10 in. length and 16 in. height, comparing the following treatments:

(*a*) a six-inch layer of *katchra* on top of the compost mass, but no earth cover;

(*b*) a two-inch layer of loose earth on top of the above *katchra* layer;

(*c*) a two-inch layer of earth-dung plaster on top of the *katchra* layer: the earth-dung plaster was prepared by mixing equal volumes of fine earth (black cotton soil) and cattle dung, along with sufficient water to form a thick plaster; cracks that formed in the plaster were closed up every day with dung paste; and

(*d*) tarred cloth treatment; a piece of drill cloth of size sufficient to cover the compost mass was given a good coating of tar on both sides, so as to

close up the pores ; this tarred cloth was placed on top of the compost mass and the edges were fixed to the glass by placing a strip of earth-dung plaster (1½ in. wide and 1 to 1½ in. thickness) along the edges of the cloth, such that the plaster extended right up to the glass surface ; cracks that formed in the plaster were closed up daily.

The jars were first filled with alternate layers of 3 in. *katchra* and 1 in. of night-soil to a height of 8 in., at which stage an inoculum containing 500 fly maggots (*Musca domestica*) was spread. Over this, a layer of *katchra* (3 in.) and one of night-soil (1 in.) were spread ; and finally a 6 in. layer of *katchra* was placed on top.

The larval inoculum was obtained from a dung heap which was kept moist (with cattle urine) and exposed to the breeding of the house fly within a cage. A mixture of gutter-fly-waste (cotton) and cattle urine was also found to offer an excellent bed for fly-breeding. A handful of the inoculum so prepared was kept on an earthen plate and the larvae were counted out by a spatula into a tin or earthen bowl till the required number was reached. In order to secure uniformity in comparison, 500 larvae were added to each jar. The night-soil used for the experiments was not noticeably contaminated with fly larvae, as shown by control trials carried out without the addition of larval inoculum, which gave only negligible fly counts.

There was a vacant space about 3 in. to 4 in. in height above the level of the compost in each jar and the top of the jar was covered by mosquito netting cloth. The emergence of flies could be easily detected by looking through the glass sides and through the mosquito netting on top.

Counts of fly emergence were made daily in the afternoon at about 5 p.m. in the following manner. The string fixing the top mosquito netting cloth was loosened and the sides of the glass jar were darkened with a black cloth. A glass plate was then placed on top of the jar and it was pressed back slowly (along with the mosquito netting cloth underneath), so as to expose a small opening in one corner of the jar, through which flies could escape. The flies inside were attracted by the daylight at the opening and were quick to come out. It was possible to control the opening, by moving the glass plate forward and backward and thus to control the rate of escape of flies such that their numbers could be correctly counted. Fly emergence usually started on the 8th or 9th day and came to a stop about the 22nd day. The rate of emergence fitted in with the curve shown in Fig. 1. The jar experiments were repeated on several occasions, giving results similar to those shown in Table I.

TABLE I

Experiments in jars

Treatment	Inoculum added	Total flies emerged	Percentag emergenc
1. *Katchra* cover	500	328	65·6
2. Loose earth-cover on top of *katchra*	,,	388	77·6
3. Earth-dung plaster treatment	,,	8	1·6
4. Tarred cloth treatment	,,	6	1·2

The data in Table I show that (*a*) the eart plaster and tarred cloth treatment are equa effective in bringing down fly emergence to negligi proportions, and (*b*) the addition of an earth co on top of *katchra* actually increases fly developme —probably due to the fact that fly larvae pre dry earth for purpose of pupation.

Various trials were carried out in jars in ord to find out the proper day on which the earth plas or tarred cloth had to be fixed after the compo was made. The data obtained indicated that t 6th or 7th day was the most effective for applicati of the treatment.

Trials were also carried out in jars in order find out the minimum period (number of days) which the earth plaster or tarred cloth had to rema in position, in order to effect destruction of the maggots. It was found that the success of the tre ment depended on the effectiveness with which supply was cut off from the compost by means the earth plaster or tarred cloth ; in other wor the destruction of flies was dependent on the esta lishment of anaerobic conditions inside the compo mass. When such anaerobic conditions were esta lished, a period of 2 to 3 days was found to be su cient to destroy the larvae and pupae.

While carrying out the above experiments, it w noted that the effect of the earth plaster or tar cloth was of a spectacular nature, in that within few minutes of the treatment, the larvae were tryi to climb up in clusters towards the surface, a within five minutes, they were found complete paralysed in bunches, without the least moveme In about three days, their bodies were being act on by bacteria and the removal of the control tre ment after three days, failed to bring them ba to life. The inactivation and destruction of t larvae were no doubt asphyxiation effects produc by cutting off of the supply of air ; and hence t methods of control reported here may be term asphyxiation methods produced by anaerobic tre ment.

SMALL PIT EXPERIMENTS

The results obtained in glass jars were next test in small pits dug in the earth, of the size of 1½

breadth, 1½ ft. in length and 1½ ft. in depth, which re filled up with alternate layers of refuse (3 in.) d night-soil (1 in.) till the pit was half-full. At is stage, an inoculum containing about 2,000 fly ggots (*Musca domestica*) was spread ; and further ers of refuse and night-soil were added till the ap came to ground-level. A further six-inch ck layer of refuse was put on top, so that the heap s about five to six inches higher than ground-el on the first day. In about five or six days, heap sank down to ground level.

Six treatments were compared in the present case, ng two pits for each treatment as noted below :

(*a*) a nine-inch thick *katchra* cover only on top, thout any earth layer over it ;

(*b*) a two-inch thick layer of dry earth spread on p of the *katchra* cover in (*a*) ;

(*c*) a two-inch thick earth-dung plaster put on the xth day after filling ; the earth-dung plaster was epared in a manner similar to that used in the jar periments and cracks formed in it were closed up ery day ;

(*d*) tarred cloth treatment applied on the sixth y, as per following details : Thick drill cloth of ze of 1 ft. 10 in. × 1 ft. 10 in. was coated twice ith melted tar on both sides, till no pores were sible when the cloth was held against the light ; is tarred cloth was placed on top of the compost t on the 6th day and its edges were fixed to the round firmly by placing a two-inch wide layer of rth-dung plaster below and a three inch wide, o-inch thick plaster above the edges all round.

(*e*) Single fire treatment, which was carried out spreading a six-inch thick layer of dry refuse top of a two-inch layer of loose earth placed as treatment (*b*), and setting fire to the refuse on 6th day after filling ; the fire usually smouldered r a quarter to half an hour ; and

(*f*) double fire treatment, on the sixth and tenth ys after filling, carried out in a manner similar treatment (*e*), but applied on two days, viz. on he sixth and tenth days after filling.

Counts of fly emergence were taken by fixing over ach pit fly-cages made of mosquito netting cloth ung over teak frames. The top folds of the mos-uito netting were tied together by a piece of string nto a bunch. When fly counts were made, the not was carefully opened and the four sides of the age were shaded with gunny cloth, when the flies ame out through the opening at the top and while hey were let out, their numbers were counted. ly counts were taken at about 5 p.m. every day.

In the case of pits and trenches where a known ount of several thousands of larvae had to be added, was found time-consuming to count them indivi-ually. Hence, recourse had to be taken to the echnique of taking mass samples of inoculum after roper mixing. For this purpose, the required num-ber of bucket-loads of the fly-inoculum material (cotton-fly-waste plus urine or dung plus urine, where fly larvae were breeding in large numbers) were spread on the ground and properly mixed, and sample portions were measured out by small tins and were counted for larval numbers. Depending on the above counts, a suitable volume of the inoculum material was added to each pit so as to give a supply of about 2,000 fly larvae. It was found that the above technique of sampling the inoculum involved an error up to 10 per cent, but since the control treatments showed a difference of 40 to 95 per cent, the technique was considered suitable for the purpose.

The data for total fly emergence obtained from one set of trials are shown in Table II.

TABLE II

Experiments in small pits

Treatments	Total inoculum count	Total fly emergence	Percentage of emergence
1. *Katchra* cover	2000	828	41·4
2. Earth cover on top	,,	964	48·2
3. Earth dung plaster	,,	56	2·8
4. Tarred cloth treatment	,,	42	2·1
5. Fire treatment on 6th day	,,	206	10·3
6. Fire treatment on 6th and 10th days	,,	92	4·6

The trials were repeated a number of times, giving results similar to those shown in Table II.

The composts made in the pits were found to show much higher temperatures (above 60°C.) than those prepared in glass jars (up to 40°C.). The difference could be attributed to the greater mass of refuse used in the former case.

A comparison of the data given in Tables I and II would show that as a result of the higher temperatures achieved by the pits, the percentage of fly emergence in the 'no-treatment' sets has shown a fall from about 70 per cent in the glass jars to a level of about 45-50 per cent in the pits. In both cases, the application of loose earth cover on top of the pits has shown a slightly increased percentage of fly emergence. The tarred cloth and earth plaster systems secure satisfactory control and reduce fly emergence to a low level of about two to three per cent on the total inoculum introduced.

Regarding fire-treatment, one fire treatment given on the sixth day, reduced fly emergence to a level of about 10 per cent on the inoculum count, but the actual number of 206 flies which emerged from an area 1½ ft. × 1½ ft. may be considered to be too high. A second fire treatment given on the 10th day after filling, brings down the fly emergence to a level of 4·6 per cent, which may be considered to be satisfactory.

Other sets of trials were carried out in pits, on the above lines, in order to examine the minimum period (number of days) for which the earth plaster or tarred cloth had to remain on top of the pits, in order to secure destruction of over 95 per cent of the fly larvae. It was found that one week's treatment from the 6th to 13th day after filling up the pits was satisfactory in the earth plaster as well as in the tarred cloth treatment. The above period of one week required, is greater than the period of three days found sufficient in the case of glass jars. The difference is attributable to the fact that conditions inside earthen pits are not so anaerobic as inside glass jars and hence a longer period of treatment is necessary to destroy the larvae and pupae in the former case.

Pilot scale trench experiments

The results obtained in small pits were next extended to pilot scale trenches of length 5 ft., breadth $1\frac{1}{2}$ ft. and depth $1\frac{1}{2}$ ft., which were fitted up with mosquito netting cages in teak frames, on lines similar to the smaller pits described above.

The trenches were filled up in a manner similar to the smaller pits, viz. with alternate layers of three inches of *katchra* and one inch of night soil. When the trench was half-full, a quantity of inoculum containing about 10,000 fly larvae (*Musca domestica*) was uniformly spread over the night-soil layer and the trench was filled up with further layers of refuse and night-soil as usual. The method of sampling the fly-larval inoculum was similar to that used in the case of the smaller pits. The treatments compared were also the same, viz. (*a*) nine-inch *katchra* cover, (*b*) two-inch loose earth cover on top of the *katchra* cover, (*c*) two-inch thick earth-dung plaster, (*d*) tarred cloth treatment, (*e*) single fire-treatment on the sixth day, and (*f*) double fire treatment, on the 6th and 10th days after filling up.

There was a slight difference, in the present case, in the manner in which the mosquito netting cage was prepared. Since the cage was 6 ft. long and 2 ft. broad, it was not found possible to tie up the top folds of the mosquito netting into a bunch on top of the cage in a manner similar to the smaller cages of the size of 2 ft.×2 ft.×2 ft. The top folds were therefore stitched together most of the way except at one end, where the folds were left loose and brought together into a bunch and tied by string. While taking fly counts, the cage was covered over with gunny cloth (in order to shade it), starting from the end farthest from the bunch opening, and the bunch was carefully opened, when the flies came out easily and their numbers could be counted.

The data obtained in the case of pilot scale trenches are given in Table III. Temperature readings (65°—70°C.) in the top nine-inch layer of compost, were in general higher than in the case of the smaller pits. This experiment also was repeated a number of times, yielding similar results.

A comparison of the data presented in Tables II and III shows that the percentage of fly emergence has come down to the order of 30-33 per cent in the case of the untreated pilot trenches, as compared to 45-50 per cent in the case of the untreated small pits. This would indicate that in the case of bigger-sized trenches used by municipalities, (size from 20 ft.×6 ft.×$2\frac{1}{2}$ ft. to 35 ft.×8 ft.×$3\frac{1}{2}$ ft.), the percentage of fly emergence is likely to be less than 20 per cent in the untreated trenches, in dry fair weather, when temperatures in the trenches mount up to 60°C. and above within 48 to 60 hours.

Table III

Fly emergence in trenches

No.	Treatment	Total fly larval inoculum	Total fly emergence	Percentage emergence
1	*Katchra* cover . .	10,000	3,177	31·77
2	Earth cover on top of *katchra* cover	,,	3,350	33·50
3	Earth-dung plaster .	,,	146	1·46
4	Tarred cloth treatment	,,	122	1·22
5	Fire treatment on 6th day	,,	858	8·58
6	Fire treatment on 6th and 10th days	,,	312	3·12

The results obtained in trenches with different treatments, viz. earth plaster, tarred cloth application and fire treatment are similar to those obtained in the case of the small pits (Table II), except that the percentage fly emergence values are lower in every case in the bigger trenches. This is no doubt due to the higher temperatures reached in the trenches as compared to the small pits.

Some trials were also carried out in order to examine whether the fixing of the tarred cloth over the trench could be simplified, by omitting the strip of earth-dung plaster that was placed along the edges of the cloth and substituting in its place a thick bund of loose earth. This simplification proved to be ineffective, for even though the size of the tarred cloth was purposely increased, in length and breadth, so that it extended one foot beyond the edges of the trench on all sides and even though a thick bund of loose earth, six inches wide and three inches thick, was placed over the edges of the tarred cloth so as to press it down to the ground, it was found that the fly larvae managed to creep their way beneath the tarred cloth and into the loose earth bund, where they pupated and later emerged as flies. The final counts obtained were about 50 to 60 per cent of those obtained in the 'control' (untreated) trenches. Therefore, the success of the tarred cloth treatment would

pear to depend essentially on the care with which e earth dung plaster is prepared and applied all ong the edges of the cloth ; a strip of the plaster ould be below the edges and a wider and thicker rip should be above the edge, so that the cloth is mly fixed to the ground, and any cracks that pear in the plaster should be closed up daily.

In the case of the pilot scale trenches, hessian ite cloth) of the variety used for tying up bales of tton goods while in transit was successfully used place of drill cloth. Since the pores are bigger in ssian, the cloth was first smeared well on both les with a slurry made by mixing equal volumes of rth, cattle dung and water and allowed to dry, fore giving a good coat of tar to each side. The eliminary treatment with earth-dung slurry was und to lessen the quantity of tar required, which as the one costly item in the preparation of the ove cloth.

Experiments with overground heaps

Most of the work reported in this paper was carried t using the pit or trench system of compost-making, t some trials were also carried out to test how far e treatments are capable of successful application the case of overground heaps. Such overground aps are recommended in the Bangalore Process for option in areas where the rainfall is heavy or e water-table is high.

Conical compost heaps of 2 ft. diameter at the ttom and 1½ ft. height were built up by placing ternate layers of refuse (3 in. thick) and night-soil in.) and keeping each layer of refuse basin-form, th the help of a thick refuse bund all along the ges, so as to prevent the night-soil from flowing t. It was found possible to add in the overground ap only half the quantity of night-soil that could used in trenches, for the same total quantity refuse used.

The treatments compared and the results obtained ere similar to those reported in Tables II and III. nce a larger surface area was exposed in the case of e overground heap as compared to trenches, the st of the treatments was found to be greater in the rmer case. The tarred cloth treatment was applied stitching a suitable piece of drill cloth into a conical ape, of a size sufficient to cover the heap, and tar- ng the cloth so prepared on both sides. The tarred ne-cloth thus prepared was slipped over the heap the sixth day after it was made and the bottom ges of the cloth were fixed to the ground by placing strip of earth-dung plaster at the foot of the heap round, then pressing the cloth edges along that aster strip and placing a second earth-dung plaster rip outside, such that the plaster covered the edges the cloth and extended to and joined with the round. The results showed that the earth plaster d tarred cloth treatments were equally applicable the case of overground heaps, but the cost of operation was about double. The fire treatment was not so effective in the case of overground heaps as in trenches.

Discussion

The experiments reported in this paper were carried out in presence of a larval inoculum containing a known count of fly larvae. This was necessary for purposes of quantitative comparison between the different treatments. The refuse and night-soil were obtained from a students' hostel area, which was being cleaned twice a day and so contained very little of fly-infestation. Controls run with the refuse and night-soil alone, without the addition of a larval inoculum, showed only negligible fly counts.

The question how far there is need for adopting any special fly control measures in the trench system of compost-making, would depend chiefly on the cleanliness of the municipal area concerned and the extent to which the refuse and night-soil are contaminated with fly eggs and larvae in the town itself. The degree of urban cleanliness varies enormously from centre to centre in India. The larval inoculum used in the present experiments gives to the compost mass a larval intensity of 10 to 20 per lb. of refuse, which should be considered to be a conservative figure as compared to larval counts found in the night-soil and refuse collected in many municipal areas. The present data have shown that even at such a conservative estimate of larval intensity and in spite of the fact that in the trench system of composting about 75 to 80 per cent of the larvae are destroyed in the mass itself in the dry season without any additional treatment and only about 20 per cent emerge as flies, still the fly emergence (in the untreated trenches) works out to a rate of more than 400 flies per square foot of trench area. Any rate exceeding a total emergence of 10 flies per square foot of area, or what could be conveniently called, a F sq. ft. value exceeding 10, should be considered to be dangerous from the point of view of public health and spread of disease. It is therefore clear that a careful watch should be kept over the rate of fly emergency from compost trenches, especially in the case of Depots which are situated adjacent to inhabited localities.

Temperature and humidity are important factors controlling the rate of fly emergence. In the dry hot season of the year, e.g. February to June, fly emergence is low at most centres and it would be unnecessary to adopt any special control measures. In the rainy and cooler period (say from July and January) F sq. ft. values should be systematically taken in compost trenches and when the value exceeds 10, a suitable fly control method would have to be applied.

Among the three methods which have been examined in this paper, viz. (*a*) earth-dung plaster method, (*b*) tarred cloth method, and (*c*) fire treatment,

the particular technique which could be adopted with success by a municipality would depend on local conditions, and the cost of application of the control technique.

The earth-dung plaster method is simple, and in Depots where there is plenty of loose earth available from newly dug trenches, the extra cost of the method lies mainly in labour charges, which may amount to about 10 to 12 annas for treating 100 sq. ft. of trench area or about 1½ to 2 annas per cartload of manure produced. The chief disadvantages of the earth plaster technique, which detract considerably from its usefulness are (i) the considerable harmful effect which an earth plaster exerts in delaying decomposition by making conditions almost anaerobic inside the trench, (ii) the difficulty of getting the fairly large quantities of loose earth and cattle dung needed for daily plastering work, and (iii) the daily close supervision that is necessary for a period of one week at least, in order to close up cracks which may appear on the surface. The earth-dung plaster method, however, may be found to be conveniently adapted to deal with small quantities of refuse, either in trenches or in overground heaps.

Treatment with fire would, on the face of it, appear to be specially suited for compost Depots, since plenty of refuse is available for burning purposes. The method involves little cost and works well in the dry season. In areas where the night-soil and refuse are not heavily infested with fly eggs and larvae, i.e. in the case of clean towns, a single fire treatment on the sixth day may be sufficient to keep down fly emergence at a low level. The chief disadvantages of the fire treatment system are that (i) in the rainy season, most of the town *katchra* comes moist to the Depot and it is difficult to obtain an equally cheap alternative supply of fuel during the above period which would take the place of dry refuse ; waste paddy-husk from paddy de-husking mills has been suggested as a suitable alternative in the rice areas ; (ii) at most municipal centres, there is a deficiency of dry refuse (*katchra*) and an excess of night-soil to be composted ; and hence diversion of a portion of the *katchra* for purpose of burning would accentuate the deficiency to a level, which would prejudicially affect the rate of decomposition of night-soil ; (iii) burning of refuse means loss of humus and nitrogen, which are valuable constituents in agriculture ; and (iv) a single fire treatment is satisfactory only at low levels of fly larval infestation but not at high levels (Tables II and III) ; a double fire treatment on the 6th and 10th days would be impracticable at most centres, due to the large quantities of refuse that would have to be diverted for the purpose.

It would thus appear that the tarred cloth treatment would be found to be best suited for adoption at most compost centres. The cost of preparing the tarred hessian cloth comes to about Rs. 10 per 100 sq. ft. of surface area ; and, with retarring at intervals, the same cloth can be used for a year. A Depot doing work at the rate of one trench per day would require a batch of seven or eight such cloths, since after seven days' use over a particular trench, the same cloth can be used for covering another trench. The labour charges for applying the border strip of earth-dung plaster all round the edges of the cloth are low and the work can normally be looked after by the regular sweeper staff employed at the Depot. The total extra expenses involved in adopting the tarred cloth method, including replacement of the cloth after a year, came to about annas 1½ to 2 per cartload of manure produced (½ a ton), in the present experiments and is likely to be below an anna per cartload of manure produced in the post-war period. Considerations of public health would warrant compelling municipalities to incur the above extra expenditure, especially in cases where the compost Depot is situated adjacent to inhabited localities.

Before concluding, it would be necessary to mention two points which require further consideration. From the data presented in Tables II and III, it would appear that the presence of a thin (two-inch) loose earth cover on top of the compost mass is actually helpful for fly development and the question may be raised as to why the loose earth cover should not be dispensed with. The two-inch earth cover has been retained in the Bangalore Process, on account of these advantages : (i) it covers satisfactorily the organic debris and thus prevents oviposition of eggs by extraneous flies from outside the trench ; this is an important matter in cases where the top *katchra* is moist and flies may be attracted to lay their eggs therein ; when once such a cycle of extraneous oviposition starts, fly control becomes much more complicated and difficult ; the earth layer simplifies the problem considerably ; (ii) a dry earth layer on top of the compost trench presents a clean appearance, keeps down fluffy refuse (leaves, paper, etc.) and prevents the same from being carried about by the wind ; and (iii) the presence of the earth layer improves microbial decomposition by conserving moisture and minimizing nitrogen loss.

Secondly, it should be noted that the present experiments have been carried out by using inoculums of the house-fly larvae only (*Musca domestica*)—the justification being that it is this type of fly which is likely to run about from compost Depots to the surrounding habitations and transmit disease organisms. Further work is in progress to extend the present studies to other types of flies which commonly haunt compost depots, e.g. the Blue-bottle fly, Stable-fly, etc.

SUMMARY

Available methods for the control of fly breeding
ompost trenches have been critically reviewed,
special reference to their workability under com-
depot conditions existing in India ; the present
ods have been found to be unsuitable and the
has been felt for simpler and cheaper methods
ntrol.

. Three simple methods have been developed for
purpose, viz. (*a*) use of an earth plaster cover,
rred cloth treatment, and (*c*) treatment by fire.
scope for each method and its limitations have
pointed out and the tarred cloth method has
preferred to the other two.

The present experiments have limited them-
s to the breeding of the house fly (*Musca domes-*
and the work is being extended to other types
es which commonly haunt compost depots.

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THE NATURE OF PHOSPHORUS IN SEWAGE, SLUDGES AND TRENCH MANURES*

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HOUGH the high phosphorus content of sewage enerally known, its fertilizing value is ascribed to its nitrogen and organic matter contents. ent investigations of the author [Joshi, 1942] shown that the phosphorus of sewage is not only ly available but also an important factor deter-ng crop yield from certain types of soils. The re of phosphoric acid in sewage and other night-manures studied by the fractionation method is ussed in this paper.

ECHNIQUE OF FRACTIONATING PHOSPHORIC ACID

l P_2O_5

ie total phosphoric acid content was determined he usual manner by igniting the material (in ge first evaporating to dryness and then igniting) and extracting the ash with HCl and determining phosphoric acid volumetrically.

Organic P_2O_5 *in 1 per cent NaOH (hot)*

For estimating the organic phosphorus the material was first treated with normal HCl (cold) overnight and then washed several times with the same. The material was then extracted with 1 per cent NaOH (hot) by leaching, till it did not yield any more coloured extract. An aliquot was then taken and excess of acid added to precipitate the organic fraction (a-humus) and filtered. The inorganic phosphoric acid was determined in the filtrate and the total P_2O_5 in the alkali extract. The difference gave the organic phosphorus extractable in alkali.

N *HCl (cold) extractable organic* P_2O_5

In activated sludge it was noted that there is an organic fraction of phosphoric acid extractable in cold

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normal HCl. In the first place the inorganic phosphorus extracted in cold *N* HCl was determined by evaporating an aliquot to dryness and taking it up with nitric acid and then estimating it volumetrically. After complete fractionation, it was noted that a difference of about 0·3 per cent was not accounted for. It was, therefore, thought that there may be an organic fraction extractable in cold normal HCl. An aliquot was therefore evaporated to dryness and ignited and then extracted in hot nitric acid and phosphoric acid estimated volumetrically. A difference of about 0·3 per cent was observed in the estimations with and without ignition. This difference was possibly due to the organic fraction which was not precipitated without ignition. As far back as 1912 Collison criticized the method of estimating inorganic phosphorus in plant substances in acid extracts. He observed that organic substances like proteins, carbohydrates and in the cases of cereals salts of phytic acid inhibited the formation of ammonium phosphomolybdate. The salts of phytic acid especially have the property of supressing the formation of precipitate markedly.

To ascertain whether the presence of some organic compounds is inhibiting the precipitation of inorganic phosphorus in the present case or whether it is some organic fraction of phosphorus which is not estimated without ignition, 25 c.c. of the HCl extract were dialysed in cellophane bag for two days. The dialysed liquid was then carefully transferred to a 100 c.c. measuring flask and the bag washed several times with distilled water. The solution was made up to 100 c.c. and an aliquot was examined colorimetrically for inorganic phosphorus. No inorganic phosphorus was present. Another aliquot was evaporated to dryness, ignited, extracted in very dilute sulphuric acid and phosphoric acid determined colorimetrically. A fairly large amount of phosphorus was found to be present; and this was naturally concluded to be an organic form of phosphorus. The results are given in Table I.

TABLE I

Percentage of P_2O_5 (N HCl extr. organic) in activated sludge

	Percentage on air dry activated sludge
P_2O_5 in N HCl without ignition . . .	1·27
P_2O_5 in N HCl with ignition . . .	1·61
Difference between the above two . .	0·34
Organic P_2O_5 (after dialysis) . . .	0·32

It is thus seen that a certain form of organic phosphorus is extracted in cold normal hydrochloric acid and that the presence of this organic phosphorus does not interfere in the precipitation of inorganic phosphorus in the acid extract.

Available P_2O_5 (calcium phosphates)

To have an idea of the phosphorus available to plants, the material was extracted with 0·002 normal sulphuric acid bufferred to *p*H 3 with ammonium sulphate. This method essentially is Truog's [1935] and has been employed by many investigators for estimating available phosphoric acid in soils. Truog extracts the soil with 200 parts of the dilute acid for half an hour and the fraction thus extracted is believed to be available. Heck [1934] observed that in this medium mostly the calcium phosphates are extracted and it is well known that calcium phosphates are readily available to plants.

Complete extraction of phosphoric acid was also tried with sulphuric acid of different strengths. It was observed in the first instance that extraction for half an hour and complete extraction did not show any striking difference. The latter was done by treating 0·2 to 0·5 gm. of the material overnight with 100 c.c. of sulphuric acid of the required strength and then washing it several times on a filter paper with the same acid. The filtrate was made up to 500 c.c. and phosphoric acid estimated colorimetrically. In the filtrate colorimetric test for the presence of Fe^{++} and Fe^{+++} was taken and it was observed that most of the soils and sludge materials did not show the presence of either in 0·002 normal or 0·01 normal sulphuric acid extracts. The presence of ferric iron was however detected in 0·02 normal sulphuric acid extracts and in extracts above this concentration. Complete extraction gave slightly higher values than half an hour extraction as could be seen from the results given in Table II.

TABLE II

Percentage of P_2O_5 extracted in 0·002 N sulphuric acid extracts

Soil (Laboratory No.)	½ hour extract	Complete extract
BS 1 . . .	0·050	0·062
BS 2 . . .	0·087	0·100
BS 3 . . .	0·018	0·025
BU 2 . . .	0·009	0·011
BU 1 . . .	0·016	0·020
Dried sludge . .	0·220	0·240

The available phosphoric acid in sewage, sludges and trench manures was determined by complete extraction of the dried material by 0·002 normal and 0·01 normal sulphuric acid.

Water-soluble P_2O_5

Water soluble phosphoric acid was determined in water extracts colorimetrically.

Sewage and sludge analysis

e analyses according to the above technique of ewage and wet activated sludge (final tank) from ctivated Sludge Plant of the Indian Institute ience, Bangalore, are given in Table III.

Table III

ionation of phosphorus in raw sewage and wet activated sludge

res in bracket represent percentage of the fraction to the total P_2O_5)

Fractions	Raw sewage (parts per 100,000)	Activated sludge percentage on air dry basis
P_2O_5 . . .	1·75	2·16
nic water soluble	0·66 (37·7)	0·46 (21·3)
$\frac{5}{N}$ H_2SO_4 extracted ganic P_2O_5	0·44* (25·1)	0·24* (11·1)
N H_2SO_4 extracted ganic P_2O_5	0·54* (30·8)	0·54* (25·6)
l extracted inorganic	0·80* (45·7)	0·89* (41·2)
$\frac{5}{1}$ extracted organic	0·10 (5·7)	0·32 (14·8)
$\frac{5}{}$ ent NaOH extracted ganic P_2O_5	0·03 (1·7)	0·28 (12·8)
ent NaOH extracted nic P_2O_5	0·04 (2·3)	0·10 (4·6)
al P_2O_5 . .	0·12 (7·8)	0·11 (5·0)

* Excluding water-soluble P_2O_5

observed from the above analysis that the portion of total phosphoric acid is in the nic form, about 85 per cent of the total P_2O_5 raw sewage and 75 per cent in the activated . The higher organic phosphorus extractable al HCl in the activated sludge as compared sewage may have its origin in the biochemical ns taking place in the process of activation. further observed that raw sewage did not give coloured extract with hot 1 per cent NaOH, the activated sludge yielded and thus it was nt that a considerable humification of organic occurred in the process of activation. Organic horus present in humus is represented by the per cent NaOH extraction and from the results lysis it is clearly seen that only a small fraction total phosphoric acid is present in the humus. of the total phosphoric acid nearly 37 per cent sewage and 21 per cent in activated sludge is er soluble (inorganic) form, naturally mostly no-calcium, sodium or potassium phosphates these salts of phosphoric acid are known to er soluble. The low amount of this fraction vated sludge is due to loss of a part of water phosphoric acid of raw sewage in the effluent. It is found on analysis that wet activated sludge contains nearly 98 per cent water and this physico-chemically retained water accounts for the water soluble phosphoric acid present in the sludge.

Nearly 68 per cent of the total phosphoric acid (including water-soluble fraction) in the raw sewage and 46 per cent in the activated sludge which is extractable in 0·01 *N* sulphuric acid could be regarded as available to plants. It has been pointed out previously that this fraction can be regarded to represent calcium phosphates and it is well known that calcium phosphates are easily utilized by the plants. The lower proportion of available phosphoric acid in the activated sludge is likely to be partly due to the lower water soluble phosphoric acid content and partly due to the conversion of a part of the inorganic phosphoric acid into organic forms by the flora taking part in biochemical processes as pointed out above.

It is thus seen that quite a large part of sewage and sludge phosphorus is in a form available to plants. In sewage moreover nearly one third of the total phosphoric acid is in the water soluble form which will naturally be in a much more available condition. Sewage and sludges hence prove potent sources of supply of phosphorus to crop plants.

Analysis of different types sludges

Some samples of sludges supplied by Mr Griffin, Officer-in-charge, Sewage Disposal Works, Okhla (Delhi), were analysed according to the above scheme. A short description of the sludges is given below.

Raw settlement sludge. The sludge was collected from sedimentation tank. The admixture with activated sludge was discontinued 3-4 hours before taking this sample.

Simplex tank sludge. The sludge was collected from the final settling tank vide Simplex aeration process.

Digested sludge. A mixture of raw settlement sludge and activated sludge was digested for production of gas. The sludge left over represents this sample.

Okalnite. This is a mixture of dried powdered digested sludge and activated sludge in 1 : 1 proportion.

It is observed from the analysis that the simplex-tank sludge is richer both in total nitrogen and phosphorus than the raw settlement sludge. It is rather unnatural that sludges obtained from the same sewage should show such a wide variation in their phosphorus content, though variations in the nitrogen content may occur to some extent due to varying rates of destruction and synthesis occurring in the various biochemical processes. The lower nitrogen and phosphoric acid content in the raw settlement sludge could be explained to some extent on the basis of presence of a somewhat larger amount

TABLE IV

Analysis of sludge samples

Constituents	Raw settlement sludge	Simplex tank sludge	Digested sludge	Okalnite
	Percentage on air dry basis			
Moisture	6·68	13·56	4·85	8·20
Loss on ignition	47·68	63·97	21·12	40·21
Carbon as 58 per cent of loss on ignition	27·65	37·08	12·25	23·30
Nitrogen (total)	3·14	6·91	1·24	3·60
C : N ratio	8·80	5·30	9·80	6·40
a-humus	12·30	16·80	3·60	8·40
Total P_2O_5	1·68	3·08	1·37	2·36
Water-soluble P_2O_5	0·011	0·18	0·007	0·06
0·002 *N* H_2SO_4 extracted P_2O_5	0·46*	1·22*	0·46*	0·94*
N HCl extracted inorganic P_2O_5	0·99*	1·49*	0·96*	1·40*
N HCl extracted organic P_2O_5	0·22	0·46	0·06	0·19
1 per cent NaOH extracted inorganic P_2O_5	0·05	0·11	0·03	0·06
1 per cent NaOH extracted organic P_2O_5	0·22	0·64	0·13	0·37
Residual P_2O_5	0·19	0·20	0·17	0·18
	As per cent to the total P_2O_5			
Water-soluble P_2O_5	0·70	5·80	0·50	2·50
0·002 *N* H_2SO_4 extracted P_2O_5	27·20	39·60	33·80	39·80
N HCl extracted inorganic P_2O_5	58·80	48·30	72·30	59·30
N HCl extracted organic P_2O_5	13·00	14·90	4·30	8·00
1 per cent NaOH extracted organic P_2O_5	13·00	20·70	9·40	15·50
Residual P_2O_5	11·30	6·50	12·40	7·60

*Excluding water-soluble P_2O_5

of sand in it, as most of the earthy matter generally sediments in the sedimentation tank from where the sample of the raw settlement sludge was obtained. This is also seen from the analysis which shows that the sludge contains a comparatively lower carbon, that is, organic matter content. The lower nitrogen content to some extent reflects on the varying nature of sewage arriving at the disposal station.

It is apparent that a considerable part of carbon and nitrogen is combusted and lost in the process of digestion. From the carbon : nitrogen ratio it further appears that the loss of nitrogen is greater than that of carbon as the carbon : nitrogen ratio becomes wider after digestion. It is stated in the description of the sludges given above that a mixture of raw settlement sludge and activated sludge is digested. The carbon : nitrogen ratios of the sludges are 8·8 and 5·3 respectively. The carbon nitrogen ratio of the digested sludge is however wid than these two, viz. 9·8.

Water soluble phosphoric acid is higher in t activated sludge (5·8 per cent of the total P_2O as compared to the raw settlement sludge (0·7 p cent of total) or the digested sludge (0·5 per ce of total).

The 0·002 normal sulphuric acid extractable fra tion which represents the available phosphoric ac is relatively high in the Simplex-tank sludge, ne in order being digested sludge and raw settleme sludge. Fraps [1932] found that out of 1·6 per ce of the total phosphoric acid in a sample of digest sludge 1·1 per cent, that is, 68 per cent of the tota was in an available form. The method employed f the determination of available phosphoric acid is n mentioned by him. From the analysis of sludg given above it is seen that our figures are rath low as compared to the figures given by Fraps.

It is further observed that the digested sludge h the highest proportion of normal hyrochloric ac extractable inorganic phosphoric acid fractio A major part of the organic matter being destroy in the process of digestion, the organic phosphor is converted into inorganic form. This inorgan form into which the organic phosphorus is converte does not seem to be of an available nature, as ar increase in the 0·002 normal sulphuric acid extractab fraction is not noted.

With reference to the fertilizing value of sewa sludges Fraps [1930] states that they could be di tinctly classed into two groups : (1) sludges fro Imhoff tanks and similar processes (digested sludges and (2) sludges from activated sludge processe He further observed that Imhoff tanks where th fermentation in the absence of air takes place, th sludge goes through an extensive decompositio leaving only the more resistant portions. Th fact makes this sludge poorer as a fertilizer. Ou analysis also supports this view as far as organi matter and nitrogen are concerned. But the avai ability of phosphoric acid is not much affected b digestion.

ANALYSIS OF TRENCH NIGHT SOIL SAMPLES

Two trench night soil samples were obtained fro the trenching grounds of the Municipal Committe Akola (Central Provinces). The samples were ob tained to study the effect of using the same so over and over again for burying and mixing with th fresh night soil dumped in the trenches. It w reported by the Secretary of the said Municip Committee that the manure in the trenches is n disposed of by way of selling it to the cultivato as this practice showed that the trenching grou became a hollow in course of time. This is becau

he fact that when the night soil is buried in these nches it contains a fairly large amount of water ch sinks down and gradually evaporates off. en water is lost the material in the trenches nks. In addition to this there is also shrinkage to decomposition of organic matter. In about to eight months the trenches come almost to nd level and in these circumstances if the trench nure is sold, material for burying the fresh night is not enough. This leads to the trenching nd becoming a hollow, allowing water to stagnate ing the monsoon and thus creating insanitary litions. It is therefore the practice of the Muni-l Committee not to dispose of the trenched night but to use the same decomposed material in the nches over and over again for burying the fresh nt soil. The author was therefore interested in effects of this process on the product of the nches. The samples of the decomposed night from the trenches were analysed and the results nalysis are given in Table V.

TABLE V

Analysis of decomposed night soil from trenches

Constituents	Percentage on air dry basis	
	Sample I	Sample II
sture	12·00	6·64
on ignition	26·70	11·25
hon (Allison's method)	14·10	4·29
ogen	1·68	0·51
ratio	8·30	8·30
mus	3·60	1·10
al P_2O_5	4·52	1·87
ter-soluble P_2O_5	0.05	0.007
2 *N* H_2SO_4 extracted P_2O_5	3·00	0·98
HCl extracted inorganic P_2O_5	4·50	1·63
HCl extracted organic P_2O_5	*nil*	*nil*
al K_2O	0·64	0·86
al CaO	9·50	8·61

The two samples show a wide difference in their mposition, showing thus admixture of a large antity of soil with sample II. The salient feature the above data is the high phosphorus content of material in comparison with the nitrogen and ganic matter contents. The trench manure and wage sludges have a common origin and hence the h phosphorus content of the former indicates nsiderable loss of organic matter and nitrogen decomposition and leaching from the material ich was dumped for years into the trenches and accumulation of phosphoric acid which generally does not sustain such losses. It is, hence, noted that the trench manures show a very high P_2O_5 : nitrogen ratio as compared to sludges or sewage.

SUMMARY

1. About 85 per cent of the total phosphoric acid in sewage is in inorganic form. Nearly 37 per cent of the total phosphoric acid in water soluble inorganic form and 68 per cent (including water soluble phosphoric acid) is in available form. It is thus observed that quite a large part of phosphoric acid in sewage can be utilized by the plants and sewage can hence be regarded as a potential source of supply of phosphoric acid to crops.

2. In sludges 60 per cent to 70 per cent of the total phosphoric acid is in inorganic form. The various fractions vary considerably according to the type of sludge. In general, water-soluble phosphoric acid in sludges is quite low as compared to that in sewage, because a major part of water-soluble phosphoric acid in sewage is lost in the effluent. Out of the total phosphoric acid 30 per cent to 45 per cent is in available form. Simplex tank sludge and activated sludge appear to be somewhat richer in organic phosphorus.

3. The analysis of decomposed night soil samples from trenches, where the same material was used for years for burying and mixing with the fresh lots of night soil, shows concentration of phosphoric acid in the material.

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STUDIES IN ROTS OF INDIAN FRUITS

I. OCCURRENCE OF LATENT AND SUPERFICIAL INFECTIONS

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That a great deal of loss occurs in different fruits due to fungal organisms needs no emphasis. Very little has so far been done in India to study them with a view to controlling, especially with reference to the fruits that are grown here. Fortunately some works have been done on citrus diseases by Chaudhuri [1933, 1936] in the Punjab, Uppal and Kamat [1936] in Poona, Cheema and Bhat [1929] in C. P., Ghatak [1938] in Calcutta, on mangoes by Das Gupta [1939] in Lucknow, on the Indian banana by Dastur [1916] in Nagpur, and on apples by Chaudhuri and Nath [1935], and Dey and Nigam [1933]. But our knowledge with reference to other common fruits is meagre, and no substantial work, so far as the author is aware, has been done in India, where many kinds of fruits are cultivated on a large scale.

Now in view of the measures that are to be adopted in effectively controlling the huge wastage that occurs in these fruits during storage, a knowledge of occurrence of the several organisms involved, and their capacity for rotting the fruits, is essential.

With a view to making a thorough investigation on the rotting of fruits due to fungi, it would be of considerable importance to know which of the organisms concerned, attack the fruit in its early stage of development but remain dormant in the epidermal or sub-epidermal tissues till the resistance of the host due to old age and associated physiological activities [Hawkins, 1921] falls too low to check their further growth and activities. It is also essential to know which of them gather on the surface of the fruit to gain entrance later. The treatment that is to follow in checking the damaging activities of the fungi will necessarily be different in the two cases. While superficial application of proper fungicides and other chemicals can effectively do away with the fungi that occur externally on the fruit, a different approach is to be made with regard to those which occur dormant within the tissues as latent infections.

In the present paper, which is the first of the series, the author contemplates to present the fungal organisms occurring on the surface and also as latent infection in three types of fruits, namely, those of *Psidium guyava* Linn. (Guava), *Zizyphus Jujuba* Lamk., and *Nephelium Litchi* Camb. Cognate observations that have been reported in India and abroad on other fruits are also presented along with this.

Previous investigations

Investigators working in various countries have reported from time to time the presence of latent infections in the tissues of different parts of plants and fruits. These infections do not become evident until suitable conditions prevail.

Shear and Wood [1913] have demonstrated the presence of latent infection by *Gloeosporium* and *Colletotrichum* in leaves, stems and fruits of a number of plants appearing apparently healthy. Dastur [1916] working on the plantain in India, found *Gloeosporium musarum* as a dormant infection in the skin of the fruit. Dastur's observations have been confirmed by Wardlaw [1931]. Wardlaw and McGuire [1932], while working on wilt disease of banana, demonstrated the presence of *Piricularia grazea* in unripe fruits.

Fulton and Bowman [1927] found in the Florida citrus the presence of *Diplodia natalensis* and *Phomopsis citri*. Their observations have been confirmed by Tisdale and West [1934] in the stem and stalk-end of ripe sweet oranges and grape fruits. Ruehle and Kuntz [1931] have also shown the presence of *Phomopsis citri* as latent infection in some fruits.

Weismann [1930] holds the hypothesis that the fungi responsible for the scab disease of apple must be present in the fruit before they are stored. Faes and Staehelin [1931] support him and suggest the presence of *Venturia inaequalis* mycelium in dormant stage in the epidermal cells of the fruit. Fulsom [1933], Bartley [1933, 1937] and Wormald [1934] all hold similar views. Others, for example, Kidd and Beaumont [1925] maintain that the scab is not due to latent infection but to the fungal spores that gather on the fruit or in the lenticels.

Hawkins [1921] has demonstrated *Colletotrichum gloeosporioides* in green grape fruits. Bates [1936] has found its occurrence as latent infection in oranges as well.

The observations of Hawkins [1921] have been supplemented by Baker and Wardlaw [1937], who found in addition, *Fusarium* sp. (? *expansum*), *Glomerella* sp. and *Phomopsis citri*. Horne [1934, 1935] suggests that *Dothiorella ribis* establishes itself as latent infection in Avocado pear before it is harvested. Baker [1938] has isolated *Colletotrichum gloeosporioides*, *Guignardia* sp., *Phomopsis* sp.

citri) and *Botryosphaeria ribis* living as latent ctions in Avocado pear fruits.

According to Baker and Wardlaw [1937], *Glome-* sp., *Colletotrichum gloeosporioides*, *Phomopsis* and *Dothiorella ribis* have been found to occur latent infections in the 'julie' mango.

Baker [1938] shows the presence of *Guignardia* sp., *mopsis* sp. (? *citri*) and *Colletotrichum gloeos-oides* as latent infection in healthy and fully wn papaw. Baker's [1938] studies on both green ripe cacao pods for latent infection yielded *etotrichum gloeosporioides* and *Phomopsis citri*. observations on immature and ripe tomato ts revealed *Phoma destructiva*, *Guignardia* sp. *Colletotrichum gloeosporioides* as latent infec-s in the epidermal and sub-epidermal tissues of lberry.

Experimental procedure

is hardly necessary to say that the outer surface he fruit in question should be perfectly sterilized e searching for latent infection. Accordingly fruits were washed in 5 per cent Borax solution in m water and then steeped in 0·2 per cent mercuric ride solution for 10 minutes and finally washed an asceptic condition with sterilized distilled er. To be doubly sure, surface washings of lized fruits were put to culture to see that they negative results. Strips of tissues from differ-regions of the fruit were then taken by means terilized scalpels and transferred to separate dishes with Coon's medium and incubated at Inocula were also taken from different depths he fruit to ascertain how deep the pathogens t occur. The area thus tested in every case sented about 5 per cent of the total area of ntire fruit.

urface sterilization made by mercuric chloride tion of the above strength, subsequent dipping bsolute alcohol for a few seconds and finally ing off the alcohol gave similar results.

or noting the fungi occurring on the surface, thy fruits were brought to the laboratory in ile containers. Twenty of each kind were rately washed with sterile distilled water. se surface washings were then poured aseptically separate small flasks containing sterilized Malt act agar, while still in liquid condition. These tures were then thoroughly shaken and plated in large sterilized petridishes. The plates were incubated at 28°C.

Fungi associated with litchi

atent infection

noculi taken from litchis of different ages showed presence of *Botryodiplodia theobromae* Pat. m. *Thyridaria tarda* Bane.) as dormant infection. It was also found that the fungus was more predominant towards the stem end than at the other end of the fruit. Out of 75 fruits under investigation only 54 showed infections at their basal end. To find out the depth of penetration, slices of tissues were taken from the rind, the endocarp, the aril and lastly from the seed. The last three did not show presence of any fungal organisms but the rind gave positive results.

As superficial organisms

A good number of different species of fungi was isolated from surface washings of the fruit. They were cultured in different synthetic agar media and identified. They are enumerated in Table I.

Table I

Fungi associated with litchi *as superficial organisms*

Absidia Blakesleeana Lendner
Mucor Silvaticus Hagem
Mucor sp.
Rhizopus nigricans Ehrenb.
Syncephalastrum racemosum (Cohn) Schröt.
Aspergillus flavipes (group) (Bainier and Startory) Thom & Church
A. flavus Link
A. nidulans Thom & Church
A. niger Van Tieg.
A. phoenicis (Cord.) Thom & Church
A. pseudo-nidulans Vuillemin
A. Sydowi Brainer & Startory
A. tamarii Kita
Penicullium decumbens Thom
P. rugulosum Thom
Alternaria sp. (? *chartarum*) Preuss F. Hoy. n. 27
Botryodiplodia theobromae Pat.
Fusarum lateritium Nees.
Helminthosporium atro-olivaceum Cook et Hark.
Oospora sp.
Pestalozzia sp.
Phomopsis sp.
Trichoderma lignorum (Tod.) Harz.

Fungi associated with guava

As latent infection

To determine the latent infection in guava tissues taken from healthy fruits of different stages of maturity were cultured separately. In most of the cases *Aspergillus fumigatus* (Frese.) Thom & Church was found as a latent pathogen. The same methods were observed in this case as with litchi.

As superficial organisms

As with litchi a good number of different species of fungi were collected from the surface washings of guava, a list of which has been given in Table II.

The fungi associated with this fruit show striking similarity when compared with those on litchi and *Zizyphus* (Table IV).

Table II

Fungi associated with guava as superficial organisms

Mucor Circinelloides Van Tiegh.
M. sp. (? *Silvaticus*) Hagem
Rhizopus nigricans Ehrenb.
Syncephalastrum racemosum (Cohn) Schröt.
Aspergillus flavus Link.
A. fumigatus (Frese.) Thom & Church
A. luchuensis Inui.
A. nanus Montag.
A. niger Van Tiegh.
A. phoenicis (Corda) Thom & Church
A. tamarii Kita
A. sp.
Penicillium decumbens Thom
Alternaria chartarum Preuss F. Hoy. n. 27
Botryodiplodia theobromae Pat.
Fusarium lateritium Ness.
F. oxysporum Schlecht.
Helminthosporium atro-olivaceum Cook et Hark.
Monilia sitophila (Mont.) Sacc.
Oospora sp.
Phoma sp.
Spondylocladium fumosum Erl.
Trichoderma lignorum (Tod.) Harz.

Fungi associated with *Zizyphus Jujuba*

As latent infection

No latent infection was observed in *Zizyphus*. About 75 fruits were examined but all gave negative results.

As superficial organisms

As in the previous cases, a good number of fungi appeared in cultures from the surface washings. The names of the fungi isolated are given in Table III.

Table III

Fungi associated with Zizyphus Jujuba *as superficial organisms*

Mucor Circinelloides Van Tiegh.
M. hiemalis Wehmer
Pilaira Sp. Van Tiegh.
Rhizopus nigricans Ehrenb.
Syncephalastrum racemosum (Cohn) Schröt.
Aspergillus flavipes (group) (Brainer & Startory) Thom & Church
A. flavus Link
A. fumigatus (Fres.) Thom & Church
A. nidulans Thom & Church
A. niger Van Tiegh.
A. parasiticus Spear.
A. tamarii Kita
Penicillium decumbens Thom
P. rugulosum Thom
Alternaria chartarum Pruses F. Hoy. n. 27.
Dendryphiella intersaminatum (Bark. et Rav.) Bub. et Rav.
Fusarium lateritium Ness
F. oxysporum Schlec.
Helminthosporium atro-alivaceum Cooke et. Hark.
Oospora sp.
Pestalozzia sp.
Phoma sp.
Phomopsis sp.
Stemphyliomma valpadisiacum Speg.

Results and discussions

With the technique described before *Botryodiplodia theobromae* has been found to be present as a latent infection in *Nephelium Litchi*, and *Aspergillus fumigatus* in *Psidium guyava*, while a negative result was obtained with *Zizyphus Jujuba* fruits.

The presence of *Aspergillus fumigatus* as latent infection was at first doubted but its continued appearance in cultures with inoculum taken from internal tissues proved its pathogenicity.

Investigations with fruits of different ages—from quite young to an advanced stage of maturity have proved that the pathogens establish themselves early in the development of fruits.

Cultures with the surface washings of litchi, guava and *Zizyphus* fruits have shown almost similar types of fungi (Table IV). The results obtained with the above fruits tally to an appreciable extent with those obtained with other fruits by workers working in other tropical countries (Table V).

From such results in our possession it will be found that the fungal flora present in tropical fruit orchards is more or less similar, and that the slight variations which are observed in the assemblage of the organisms on the fruit-surface should be correlated with the climatic conditions and the regional differences of the countries concerned.

Table IV

Fungi from surface washings of litchi guava and zizyphus fruits

Fungi	Recorded on		
	Litchi	Guava	*Zizyphus*
Absidia Blakesleeana	+	—	—
Mucor circinelloides	—	+	+
M. hiemalis	—	—	+
M. silvaticus	+	+	—
Mucor sp.	+	—	—
Pilaira sp.	—	—	+
Rhizopus nigricans	+	+	+
Syncephalastrum racemosum	+	+	+
Aspergillus flavipes (group)	+	—	+
A. flavus	+	+	+
A. fumigatus	—	+	+
A. luchuensis	—	+	—

TABLE IV—*contd.*

ngi from surface washings of litchi, guava and zizyphus fruits—contd.

Fungi	Received on		
	Litchi	Guava	*Zizyphus*
. nanus	—	+	—
. nidulans	+	—	+
. niger	+	+	+
. parasiticus	—	—	+
. phoenicis	+	+	—
. pseudo-nidulans	+	—	—
. Sydowi	+	—	—
. tamarii	+	+	+
. sp.	—	+	—
Penicillium decumbens	+	+	+
P. rugulosum	+	—	+
Alternaria chartarum	+	+	+
Botryodiplodia theobromae	+	+	—
Endryphiella intersaminata	—	—	+
Fusarium lateritium	+	+	+
F. oxysporum	—	+	+
Helminthosporium atro-olivaceum	+	+	+
Monilia sitophila	—	+	—
Nigrospora sp.	+	+	+
Pestalozzia sp.	+	—	+
Phoma sp.	—	+	+
Phomopsis sp.	+	—	+
Pleurodochladium fumosum	—	+	—
Pleurophyliomma valparadisiacum	—	—	+
Trichoderma lignorum	+	+	—

SUMMARY

. The fungal organisms responsible for causing it rots may be grouped under two headings ording to (1) whether they gain access into the it during the latter's development and remain re in a dormant condition (i.e. latent infection) till the normal resistance of the fruit declines much enough to allow their further growth and activities, or (2) whether the pathogen or its spores remain firm on the fruit surface to gain an access inside, through accidental wounds or bruises or by direct penetration of the skin (i.e. superficial infection) of the fruit.

2. An account of the previous investigations carried on in different countries has been given wherein it has been conclusively shown that the latent pathogens enter into the fruit at its early stage of development and remain dormant in its tissues to produce visible rotting when the fruit is at its advanced stage of maturity.

3. *Botryodiplodia theobromae* and *Aspergillus fumigatus* have been found to occur as latent infections in the fruits of *Nephelium Litchi* and *Psidium guyava* respectively, while in those of *Zizyphus* no latent infection could be observed.

4. A comparative account of the fungi isolated from surface washings of different fruits by different workers has been given which shows that the pathogens present in orchards of tropical countries are more or less similar.

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TABLE V

Results obtained with litchi, guava and zizyphus fruits and those obtained with other fruits by different workers

Fungi	Recorded on						
	Litchi	Guava	*Zizyphus* fruits	Mango (Baker and Wardlaw)	Banana (Wardlaw)	Grape fruit (Baker and Wardlaw)	Gramineae (Bunting)
Absidia Blakesleeana	+	—	—	—	—	—	—
Acrothecium lunatum	—	—	—	+	+	+	+
Alternaria chartarum	+	+	+	—	—	—	—
Ascomycete sp.	—	—	—	—	—	+	—
Aspergillus flavipes	+	—	+	—	—	—	—
A. flavus	+	+	+	—	—	—	—
A. fumigatus	—	+	+	—	—	—	—
A. luchuensis	—	+	—	—	—	—	—
A. nanus	—	+	—	—	—	—	—
A. nidulans	+	—	+	—	—	—	—
A. pseudo-nidulans	+	—	—	—	—	—	—
A. niger	+	+	+	+	+	+	—
A. parasiticus	—	—	+	—	—	—	—
A. phoenicis	+	+	—	—	—	—	—
A. Sydowi	+	—	—	—	—	—	—
A. tamarii	+	+	+	—	—	—	—
Botryodiplodia theobromae	+	+	—	—	+	+	+
Aspergillus sp.	—	+	—	—	—	—	—
Cladosporium herbarum	—	—	—	+	+	+	—
Clasterosporium maidicum	—	—	—	+	+	+	+
Colletotrichum gloeosporioides	—	—	—	+	+	+	—
Coprinus sp. and other Basidiomycetes	—	—	—	+	—	+	—
Dendryphiella intersaminata	—	—	+	—	—	—	—
Dothiorella ribis	—	—	—	+	+	+	—
Eidemia sp.	—	—	—	—	+	+	—
Fusarium sp. (? *expansum*)	—	—	—	—	—	+	—
F. lateritium	+	+	+	+	—	+	—
F. oxysporum	—	+	+	—	—	—	—
F. sambucinum	—	—	—	—	+	+	—

TABLE V—*contd.*

Results obtained with litchi, guava and zizyphus fruits and those obtained with other fruits by different workers—contd.

Fungi	Recorded on						
	Litchi	Guava	*Zizyphus* fruits	Mango (Baker and Ward-law)	Banana (Wardlaw)	Grape fruit (Baker and Wardlaw)	Gramineae (Bunting)
ninthosporium atro-olivaccum	+	+	+	+	—	—	—
nodendrum cladosporioides	—	—	—	—	+	+	—
ilia sitophila	—	+	—	—	—	—	—
ar circinelloides	—	+	+	—	—	—	—
hiemalis	—	—	+	—	—	—	—
ilvaticus	+	+	—	—	—	—	—
or sp.	+	—	—	+	+	+	—
ospora oryzae	—	—	—	+	+	+	+
ora sp.	+	+	+	—	—	+	—
cillium decumbens	+	+	+	—	—	—	—
igitatum	—	—	—	+	—	+	—
a'icum	—	—	—	+	—	+	—
gulosum	+	—	+	—	—	—	—
'ozzia leprogena	—	—	—	+	+	+	+
'ozzia sp.	+	—	+	—	—	—	—
i sp.	—	+	+	—	—	—	—
opsis sp.	+	—	+	+	+	+	—
phthora palmivora	—	—	—	—	—	+	—
rasitica	—	—	—	—	—	+	—
laria sphaerosperma	—	—	—	—	+	+	+
ra sp.	—	—	+	—	—	—	—
doplea trifolii	—	—	—	—	+	+	—
opus nigricans	+	+	+	+	+	+	—
haromyces sp.	—	—	—	+	—	+	—
azzinia ornata	—	—	—	+	—	—	—
dylocladium fumosum	—	+	—	—	—	—	—
phyliomma valparadisiacum	—	—	+	—	—	—	—
ephalastrum racemosum	+	+	+	—	—	—	—
hoderma lignorum	+	+	—	+	+	+	—

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STUDIES IN THE PERIODIC PARTIAL FAILURES OF THE PUNJAB-AMERICAN COTTONS IN THE PUNJAB*

XVI. APPLICATION OF LATE SOWING AS A GENERAL PRACTICE

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The usefulness of concentrating sowings in June for amelioration of *tirak* in cotton on all *tirak*-promoting soil conditions has been stressed in a recent publication [Dastur *et al.*, 1944]. The introduction of late sowing necessitated the consideration of its reactions on the normal agricultural programme and a thorough study of the problems associated with the wide adoption of this measure. Late sowings of cotton meant less competition between wheat harvest and cotton sowing and thus ensured timely arrival of grains to the godown. On the other hand, certain agricultural difficulties were feared to be associated with this practice. (1) Light showers before the emergence of the seedlings from the ground were likely to affect germination very seriously so as to occasion resowings which, to make matters worse, were liable to be re-encrusted. (2) As the late-sown crop is more tender and succulent by the time jassids appear, it would fall an easy prey to this insect pest in a year of heavy infestation. (3) A late-sown crop would require an extra irrigation late in October or in the beginning of November. This would involve a keen competition for water at the time of sowing *rabi* crops. (4) A late-sown crop was apt to mature late and thus exposed to greater damage by frosts. It was necessary to obtain reliable evidence to test the validity of these apprehensions and to provide satisfactory solution of those which were real difficulties.

The first difficulty could be overcome by breaking crust in time. A hand crust breaker, to be described later, has been devised for the purpose. Other points are discussed below.

Damage from jassids to the June sowing

Jassid is a well known insect pest of cotton and in the Punjab it appears in larger numbers during the months of August and September when the weather is generally warm and humid. The severity of jassid attack varies with locality and season depending upon the amount and distribution of monsoon. Whereas the damage is of rare occurrence in Multan and is less frequent in Montgomery, the eastern tracts are exposed to damage periodically.

The damage from jassids starts from the margins which become light yellow in appearance and assume characteristic curling on the lower side. There is also injury to the softer regions of the leaves in

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atches. Anthocyanins develop in the affected reas which ultimately die.

A crop may suffer more or less from jassids in a articular year depending upon other factors, e.g. arietal susceptibility, incidental concurrence of rrigation and rain in August and September, con-entration of nitrogen, sowing time and the growth nade by the plants. June-sown crop is more ucculent by the time jassids appear. Consequent-y it falls a prey to this insect more easily than a lay-sown crop. Careful observations of plots under une-sowings in several field experiments conducted 1940-41, which was a jassid year, showed one ew feature hitherto unobserved. The crop which ad covered the soil before jassids appeared was ot as much damaged as the crop which could not over the soil for one reason or the other. This observation gave clue to the influence of spacing on the incidence of jassid attack.

A simple spacing experiment was laid out at Lyallpur in 1941-42 on 4F cotton sown on 19 June to test the validity of the above observation. The spacings were S1=1 ft.×1 ft., S2=1½ ft.×1⅓ ft., S3=2 ft. × 2 ft. and S4=2½ ft. × 2½ ft. Six replicates were kept. Jassids appeared in August and the observations showed that attack was very little in the two close spacings where the crop had completely covered the soil. The damage to the wide spacings was very conspicuous. Similarly the plants that had remained stunted due to surface salinity or alkalinity suffered much more than the plants which had made normal growth. There was a steady decline in the yield and boll weight as the spacings became wider and wider (Table I).

TABLE I

Effect of spacing on yield and boll weight of June-sown 4F cotton, Lyallpur, 1941-42

	S¹ (1 ft.×1 ft.)	S² (1½ ft.×1⅓ ft.)	S³ (2 ft.×2 ft.)	S⁴ (2½ ft.×2½ ft.)	S.E.	Remarks
Yield in md. per acre . .	16·79	14·15	11·45	8·30	±0·84	Previous crop, cotton
Boll wt. in gm.	2·55	2·33	2·04	1·91	±0·101	Date of sowing, 19 June

The above experiment was repeated in 1942-43 which too happened to be a year of heavy jassid infestation. In addition to 4F, a susceptible variety, 289F/124, was included in the experiment. The previous observations regarding the relation of spacing with jassid attack were confirmed and the yield and the boll weight results were similar to those of the preceding season in the case of 4F cotton (Table II). The jassid susceptible variety 289F/124 was badly attacked in all the spacings

TABLE II

Effect of spacing on yield and boll weight of June-sowing, Lyallpur, 1942-43

	Variety	S¹ (1 ft.×1 ft.)	S² (1½ ft.×1⅓ ft.)	S³ (2 ft.×2 ft.)	S⁴ (2½ ft.×2½ ft.)	S.E.	Remarks
Yield in md. per acre	4F	16·34	14·85	8·84	8·07	±0·698	Previous crop, cotton
	124F	13·79	8·85	6·03	3·97	±0·698	
Boll wt. in gm. .	4F	2·58	2·38	1·90	2·135	±0·149	Date of sowing, 21-22 June
	124F	2·89	2·72	2·50	2·165	±0·149	

o begin with, but speedier rate of recovery in closer pacings helped greatly to improve its yield and oll weight. The general trend of results is similar o 4F.

In the year 1943-44 the same experiment was epeated with 4F and L.S.S. which were relatively nore jassid resistant varieties. All the previous bservations were confirmed with the only difference hat there was no definite improvement in boll eight with closer spacing (Table III).

No attempt was made to determine jassid population under different spacings. The object of this paper is to bring to the notice of scientific workers on jassids this important observation made during the investigations on *tirak* and to show that twofold benefit was derived by adopting close spacing for late-sown crops, viz. (1) less damage by jassids, and (2) an increase in plant number per acre to make up for a decrease in bearing. Close spacing thus remedies two shortcomings of late sowings.

TABLE III

Effect of spacing on yield and boll weight of June-sowing, Lyallpur, 1943-44

	Variety	S^1 (1 ft. × 1 ft.)	S^2 (1½ ft. × 1½ ft.	S^3 (2 ft. × 2 ft.)	S^4 (2½ ft. × 2½ ft.	S.E.	Remarks
Yield in md. per acre	4F	16·01	11·99	8·18	6·37	±0·933	Previous crop, cotton
	L.S.S.	13·26	10·25	8·86	7·08	±0·933	
Boll wt. in gm.	4F	2·19	2·00	1·97	2·00	Differences insignificant	Date of sowing, 19-20 June
	L.S.S.	2·07	2·04	2·13	2·05		

The increase in yield with close spacing is not to be attributed in full to greater resistance to jassid attack under these conditions but it is in good part the direct outcome of larger number of plants. The relative contribution of each factor cannot, however, be separately assessed.

THE DATE OF LAST IRRIGATION FOR LATE SOWINGS

Studies with regard to the last irrigation to cotton in relation to the date of its sowing were undertaken at Mian Channun, Iqbalnagar and Multan during 1940-41. The treatments comprised all combinations of four sowing dates and two varieties (K25, 289F/43) in six blocks of 4 main plots each (D''' V confounded) with subplot arrangement for the late waterings as variables. Three watering types, viz. W1, last watering on 30 September, W2, last watering on 15 October, and W3, last watering on 30 October, were allocated to the subplots to obtain precise information on the utility of late waterings for early or the late sowings. The experiments were repeated at the first two places during 1941-42 which had particularly hot and dry October.

Analysis of variance of the yield data, individually for the different experiments, revealed that the main effect of watering was significant, in 3 out of 5 cases. It did not attain significance at Iqbalnagar and at Multan due to high experimental errors. As the mean square for error in these two experiments was of the same order, the results were pooled and the linear response to watering came out significant.

Summarized results for the two seasons are provided in Table IV. Watering during October was necessary in all areas. The magnitude of increase in yield was, however, small. Besides, irrigation after 15 October did not benefit the crop. In one case only the difference between the two October waterings was significant.

TABLE IV

Results of yields in maunds per acre with three watering types

Watering	d^1 (May, 2nd week)	d^2 (May, 4th week)	d^3 (June, 2nd week)	d^4 (June, 4th week)	Mean	S.E.
			Iqbalnagar and Multan (1940-41)			
W1	11·83	11·44	12·75	14·19	12·55	±0·389
W2	11·16	14·04	12·85	14·30	13·08	
W3	12·27	14·87	14·05	13·35	13·64	
			Iqbalnagar (1941-42)			
W1	18·06	20·14	19·19	18·31	18·92	±0·46
W2	19·33	22·01	21·43	20·36	20·78	
W3	19·39	23·25	20·53	19·15	20·58	
			Mian Channun (1940-41)			
W1	11·84	13·27	12·49	10·21	11·95	±0·318
W2	10·55	12·48	13·06	10·22	11·58	
W3	13·40	13·42	15·38	10·22	13·10	
			Mian Channun (1941-42)			
W1	9·54	10·51	12·19	10·38	10·66	±0·242
W2	9·55	10·85	12·89	11·95	11·31	
W3	9·83	11·49	13·64	11·66	11·66	

he interaction, dates × watering, was revealed to insignificant everywhere. So there was no erential behaviour of late waterings with sowing es, and watering could be safely withheld after middle of October to the last sowings as well he early sowings. It may be added that the urable responses to late sowing already report- by Dastur *et al.* [1944] were all obtained from riments where irrigation to all the sowing s was simultaneously stopped on or about 15 ber. This is an additional proof to show that the need for any extra irrigation to late sowing, in particular, does not arise.

Danger of frost to late sowing

The progressive total of *kapas* collected up to each picking was expressed as percentage of the respective aggregate yield of the different sowing dates in two experiments conducted in 1940-41 to ascertain how late the crop arrival becomes when the sowings are done in June. The results are presented in Table V.

Table V

Percentage of total crop picked up to each picking,-(1940-41)

Khanewal.

Sown on	Dates of picking							
	43F				K25			
	15—20 Oct.	15—20 Nov.	15—20 Dec.	10th Jan.	15—20 Oct.	15—20 Nov.	15—20 Dec.	10th Jan.
th May)	41·0	77·5	90·5	100·0	33·7	80·2	92·7	100·0
th May)	29·0	66·0	91·5	100·0	21·6	70·6	91·0	100·0
th June)	..	67·5	90·5	100·0	..	60·5	90·8	100·0
h June)	..	60·0	89·5	100·0	..	44·6	86·6	100·0

Brucepur

Sown on	Dates of picking							
	43F				L.S.S.			
	26th Oct.	26th Nov.	18th Dec.	8th Jan.	26th Nov.	18th Dec.	8th Jan.	30th Jan.
May)	49·0	88·5	98·0	100·0	32·4	72·4	96·0	100·0
May)	44·5	88·0	99·0	100·0	38·0	79·0	98·0	100·0
June)	56·7	86·7	97·6	100·0	41·5	83·0	97·5	100·0
h June)	..	80·0	98·0	100·0	36·0	76·0	98·0	100·0

e crops finished at the same time whether were sown in May or June. Ninety per cent op for 43F and K25 and 75 per cent of crop .S.S. was picked by the 3rd week of December r all sowings. L.S.S. is known to be a late ty, still the crop arrival was of the same order e different sowings. Thus by late sowing the does not mature late. This finding was con- d by results of experiments in other seasons. the cotton growing tracts of the Punjab the generally visits towards the Christmas and there is no evidence of any special danger to sowing in comparison to early sowing. A ion of the early crop is as much exposed to as the late one, because it is the late formed that are generally affected.

Discussion

The difficulties surmized to be involved in the practice of late sowing are either unreal or they can be successfully overcome. The need of late irrigation and the danger of frost to June-sowings seem to be based upon the assumption that fruiting is delayed in the deferred sowings to the same extent as the delay in the sowing time. The study of the crop arrival at harvest has proved that major portion of the crop is picked irrespective of the sowing date by the time the frost would generally appear. This was expected in view of the findings of Dastur and Mukhtar Singh [1943] that the onset of flowers is shifted forth by $\frac{1}{3}$ the interval between the dates of two sowings; the peak in flowering is delayed

only by a few days and the cessation of flowering is hardly affected. Hence the assumption that by sowing in June the crop would mature late is not well-founded. This, however, does not rule out the possibility of slightly greater damage to later sowings in a year when the frost appears sometime in November, though such early frosts are of rare occurrence. Of late, 1932 was the only year when frost was recorded as early as November. In such years the cotton crop may suffer to an extent depending upon the degree of delay in the crop which in turn is controlled by other factors also, viz. variety, season, insect attack (the crop becomes late in a white-fly year), nitrogen level and water supply operating singly or in combination. To these may be added sowing date as only one of the factors whereby late crop may be affected by frost relatively to a greater degree.

The experimental evidence collected to determine the need of late waterings for late sowings also shows that late sowing does not require preferential treatment with respect to late waterings. Watering to cotton can safely be withheld from the middle of October irrespective of the sowing date.

Late sowing is certainly affected more severely by jassids as compared with the early sowing under similar conditions of variety, spacing, watering, nitrogen level, etc., but the damage from this inspect pest, even in the worst jassid year, can be reduced to an insignificant level by a correct appreciation of the spacing that would enable the crop to cover the ground before jassids appear.

Till recently, the established practice has been to sow cotton in April and May at 3 ft. distance between the rows and at 1½ ft.—2 ft. within the rows. The general mass of cultivators has, however, been sowing cotton by broadcast method. The popular ideal for spacing is implicit in the maxim *dango dang kapas*, i.e. cotton be spaced at *dang** distance. Sowings in early June were done in the past only in those fields where the normal sowings had to be postponed to June by unusual canal enclosures or resowings were necessitated through one or more of the incidental mishaps, viz. rain before or during germination, damage from hailstorms or insects such as locusts, chrotogoners or semilooper. Under such circumstances no change in the spacings was made. It can, therefore, be conceived why such fields suffered in the end from inadequate bearing and were in addition attacked by jassids to a greater degree. The low yields obtained from such late-sown fields prejudiced the cotton grower in favour of early sowings. The need for closer spacings than normal in June-sowings to make up for decreased bearing has been stressed earlier. This alliance is further strengthened by the association of close spacing with jassid attack shown here, and in its realization in practice lies the simplest and cheapest method of controlling this insect.

It cannot be overemphasized that sowing in the different localities must be completed within the optimum sowing range provided in Schedule B [Dastur *et al.*, 1944] because there is real danger from jassids to fields sown after the last dates indicated. Light showers before the seedlings come out are liable to affect germination very seriously by encrusting the soil surface. Crust breaking must be undertaken in June in such cases to ensure germination. In the event of a heavy precipitation in young stages or during germination water should be let out immediately followed by crust breaking in the latter case. If for one reason or the other resowing is necessitated, use of still closer spacing is imperative.

* A *dang* is a handstick of bamboo about 5-6 ft. long.

Summary

Most of the apprehensions linked with late sowing in practice are not well-founded and these are expected to fade away with familiarity. June sowings do not require any additional watering after the middle of October. Besides, June-sown crop practically finishes at the same time as the May-sown and thus there is no special danger of frosts to the former. The damage from jassids can also be considerably reduced in late sowing, if the spacing is kept close enough to cover the ground before the appearance of the insect. The knowledge of these facts will remove many misapprehensions and make late sowing a practical and profitable proposition.

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A NEW METHOD OF ESTIMATION OF TOTAL SOLIDS OF SOIL EXTRACTS AND WATERS

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usual method [A.O.A.C. 1935] of determina- of total salts or total solids in solution is to orate a convenient aliquot on water bath to ess and then dry the residue to a constant ht in an oven, cool and weigh. During pro- d evaporation, soluble bicarbonates specially kaline earths are liable to decompose to a certain nt with an uncertain loss of CO_2 and final loss ne weight of the residue. The result is that if analyses the original solution for different acid basic radicals and combines them into salts um total of the salts would always be greater the originally determined total solids. Again e solution contained salts with water of crys- ation, the water is bound to come with the ue in uncertain amounts and the sum total of alts would always be lower than the total solids rmined by the evaporation method. Thus one ys gets lower or higher total salts and it is only sionally that the sum of individually deter- d salts and total solids agree with each other. es II and III will afford numerous instances of eciable discrepancies between the total solids he usual method and the total salts. Hence is a real necessity for a reliable method of rmination of total solids of soil extracts and rs.

n [1942] found that sum of acid radicals of an ous extract when multiplied by 1·5 gave a quite close to the actual amount of total salts. was found to agree quite well with the analy- results of a large number of workers dealing widely different subjects. The purpose of the nt paper is to deal with this method and to see far it applies to soils and waters from all parts ndia.

Relation between acidic and basic radicals of a salt or a sum of salts

the case of a water or water extract one generally s for the bases Na, K, Ca and Mg and acid radi- CO_3, HCO_3, SO_4, Cl and NO_3. Acids and bases hen combined to form salts in the usual method ombination, based on the solubility of the salts their capacity to remain in solution in presence ch other. If the salts of each of the bases with of the given acid are considered, the salt/acid es (molar) come out as detailed in Table I.

us if only Na salts are present, the factor could been taken to be 1·53, for K salts 1·89, for Ca and for Mg 1·26 ; when all the salts are present, the mean of all the bases Na, K, Ca and Mg is taken and that comes out to be 1·53. To simplify calculation it may be taken to be simply 1·5.

A common observation is that in an average soil extract or water, Ca and Na are the most predominant bases and they have got salt/acid values quite close to each other, i.e. 1·53 and 1·46 giving a mean value of 1·5. Mg and K with widely differing factor are present in much smaller amounts than the other two bases.

Materials and methods of estimation

The soils reported in the paper, were all uncultivated ones. The extraction for analysis of water extracts were carried out by soaking 100 gm. of soil in 500 c.c. of CO_2 free distilled water and leaving the soil suspension overnight with frequent shakings. The filtration of the soil suspension was done by Pasteur Chamberland filters.

Total solids, calcium and magnesium

100 c.c. of the extract were taken in a weighed platinum basin and evaporated to dryness on a water bath. It was then dried in an air oven kept at 105°C. and cooled in a desiccator and weighed to a constant weight. The residue was total solids. After the final weight was taken it was redissolved in water and if there was any difficulty in solution HCl was used. Ammonia was then added, the solution again acidified with a few drops of acetic acid and treated with ammonium oxalate to precipitate calcium. The precipitate of calcium oxalate was decomposed with dilute H_2SO_4 and titrated with decinormal $KMnO_4$.

The filtrate and the washings were concentrated, ammonified and treated with sodium phosphate. It was left for 24 hours. The precipitate of magnesium ammonium phosphate was washed with ammonical distilled water, dried, ignited and weighed as magnesium pyrophosphate.

Carbonate, bicarbonate and chloride

A 100 c.c. aliquot was titrated with N/50 H_2SO_4 with phenolpthalein indicator. The titer corresponded to carbonates.

Methyl orange was then added to the same aliquot and titration with the standard acid was continued till the end point was reached.

The solution was then titrated against N/100 $AgNO_3$ with 1 per cent potassium chromate indicator for chlorides.

Sulphate

100 c.c. of the extract were treated with concentrated HCl boiled and treated with excess $BaCl_2$ solution. The precipitate of $BaSO_4$ was washed, dried and ignited and weighed as $BaSO_4$. The rapid volumetric method of Puri [Puri and Ashgar, 1938] may also be followed.

Potassium

100 c.c. aliquot was evaporated to dryness treated with HCl and 1 c.c. of platinic chloride. The residue was washed with 80 per cent alcohol and weighed.

Sodium

Sodium was obtained by difference. Acids and bases were combined to form salts after the method of combination as suggested by Leather [1902]. Excess acid was supposed to be combined with sodium.

Nitrate

40 gm. of soil were treated with 200 c.c. of distilled water with about a gm. of $CaSO_4$ to aid filtration. The soil suspension was filtered and the nitrate was estimated by phenol disulphonic acid method. The comparison of the yellow colour was done with the standard dellow slides of the Lovibond Tintometer.

The samples of water were obtained from various sources. They were usually sent to the Institute for analysis and advice as regarys their agricultural and household uses. The methods of analysis in the case of waters were the same as followed in the case of soil extracts.

TABLE I

Salt /acid figures for different salts

Salt/acid for	CO_3	HCO_3	SO_4	Cl	NO_3	Mean
Na	1·77	1·38	1·48	1·63	1·37	1·53
K	2·30	1·64	1·81	2·09	1·63	1·89
Ca	1·67	1·34	1·41	1·56	1·32	1·46
Mg	1·10	1·10	1·25	1·34	1·18	1·26
					Mean	1·56

TABLE II

Total soluble salts of soil extracts (percentage on soil)

(Each number under depth indicates 1 ft. sample below surface)

Depth	Acids	Bases	Total salts	Acids × 1·5	Total solids by evaporation
Akola soil					
1	·0471	·0171	·0642	·0707	·0525
2	·0547	·0214	·0761	·0821	·0575
3	·0727	·0290	·1017	·1091	·0700
4	·0818	·0319	·1137	·1227	·0825
5	·0995	·0393	·1388	·1493	·0975
Anakapalle soil					
1	·0234	·0106	·0340	·0351	·0400
2	·0246	·0108	·0354	·0367	·0400
3	·0207	·0087	·0294	·0311	·0400
4	·0206	·0094	·0300	·0309	·0400
5	·0296	·0148	·0444	·0444	·0725
Berhampur soil					
1	·0220	·0107	·0327	·0330	·0350
2	·0229	·0235	·0364	·0344	·0350
3	·0273	·0155	·0428	·0410	·0425
4	·0220	·0125	·0345	·0330	·0450
5	·0280	·0170	·0450	·0420	·0475

TABLE II- *contd.*

Depth	Acids	Bases	Total salts	Acids × 1·5	Total solids by evaporation
Chandkhuri soil					
1	·0250	·0101	·0351	·0375	·0200
2	·0272	·0110	·0382	·0408	·0250
3	·0290	·0116	·0406	·0435	·0250
4	·0196	·00079	·0275	·0294	·0275
5	·0152	·0059	·0211	·0228	·0250
6	·0141	·0059	·0200	·0212	·0275
Coimbatore soil					
1	·0177	·0067	·0243	·0264	·0350
2	·0197	·0075	·0272	·0294	·0325
3	·0468	·0170	·0638	·0695	·0550
4	·0438	·0147	·0580	·0657	·0500
Delhi soil					
1	·0399	·0150	·0549	·0599	·0425
2	·0284	·0105	·0388	·0425	·0400
3	·0283	·0104	·0387	·0425	·0375
4	·0326	·0122	·0448	·0489	·0425
5	·0309	·0102	·0411	·0464	·0400
Gurdaspur soil					
1	·0468	·0211	·0679	·0720	·0835
2	·0573	·0217	·0790	·0860	·0840
3	·0325	·0110	·0435	·0488	·0600
4	·0342	·0248	·0490	·0513	·0610
5	·0439	·0202	·0641	·0658	·0760
Hagari soil					
1	·01107	·0499	·1606	·1661	·1350
2	·2251	·1196	·3447	·3377	·3325
3	·5566	·2839	·8405	·8349	·8450
4	·5640	·2815	·8455	·8460	·8550
5	·3371	·1809	·5180	·5057	·5050
Haripur soil					
1	·0507	·0203	·0711	·0762	·0875
2	·0484	·0192	·0680	·0726	·0775
3	·0478	·0175	·0673	·0717	·0800
4	·0585	·0243	·0828	·0878	·1050
5	·0469	·0189	·0658	·0704	·0750
Indore soil					
1	·0442	·0163	·0605	·0663	·0550
2	·0335	·0098	·0433	·0503	·0400
3	·0416	·0154	·0570	·0624	·0500
4	·0436	·0156	·0529	·0654	·0550
5	·0358	·0129	·0489	·0537	·0425
Jorhat soil					
1	·0262	·0095	·0357	·0393	·0705
2	·0200	·0105	·0305	·0300	·0500
3	·0213	·0112	·0325	·0320	·0520
4	·0177	·0085	·0262	·0266	·0370
5	·0177	·0094	·0271	·0266	·0395
Kangra soil					
1	·0320	·0140	·0460	·0480	·0720
2	·0449	·0196	·0645	·0674	·1060
3	·0363	·0137	·0500	·0545	·1045
4	·0345	·0165	·0510	·0518	·0768
5	·0527	·0228	·0755	·0791	·0970

TABLE II—*contd.*

Depth	Acids	Bases	Total salts	Acids × 1·5	Total solids by evaporation
Karimganj soil					
1	·0294	·0140	·0434	·0441	·0650
2	·0314	·0156	·0470	·0471	·0700
3	·0462	·0337	·0906	·0693	·0950
4	·0376	·0190	·0566	·0564	·0750
5	·0376	·0193	·0569	·0564	·0750
Kharua soil					
1	·0647	·0248	·0895	·0971	·0625
2	·0464	·0246	·0710	·0696	·0475
3	·0491	·0192	·0683	·0737	·0425
4	·0417	·0144	·0561	·0626	·0450
5	·0376	·0102	·0478	·0564	·0450
Kheri soil					
1	·0407	·0198	·0605	·0611	·0425
2	·0450	·0156	·0606	·0675	·0400
3	·0370	·0139	·0509	·0555	·0375
4	·0437	·0059	·0491	·0656	·0450
5	·0438	·0039	·0477	·0657	·0450
Koilpatti soil					
1	·0814	·0338	·1152	·1221	·0925
2	·0114	·0627	·1941	·1971	·1650
3	·8165	·3665	1·1830	1·2248	1·2530
4	1·3379	·5869	1·9248	2·0069	2·1900
5	1·2321	·5380	1·7701	1·8482	1·9300
Labhandi soil					
1	0·0179	·0060	·0239	·0269	·0360
2	·0179	·0053	·0232	·0269	·0345
3	·0192	·0067	·0259	·0288	·0315
4	·0436	·0160	·0596	·0654	·0535
5	·0463	·0162	·0625	·0695	·0569
Lahore soil					
1	·0423	·0162	·0585	·0635	·0575
2	·0746	·0428	·1174	·1119	·1150
3	·1552	·0721	·2273	·2328	·2825
4	·1458	·0768	·2226	·2187	·2300
5	·1647	·0732	·2379	·2471	·2450
Lyallpur soil					
1	·0413	·0201	·0614	·0620	·0600
2	·0659	·0267	·0926	·0989	·1000
3	·0886	·0419	·1305	·1329	·1825
4	·0953	·0191	·1144	·1430	·1650
5	·0702	·0265	·0976	·1053	·1500
Malir Farm, Karachi soil					
1	·1674	·0985	·2659	·2511	·3200
2	·1215	·0708	·1923	·1823	·1900
3	·1797	·0909	·2706	·2696	·2700
4	·1905	·0952	·2857	·2858	·3050
5	·1367	·0747	·2114	·2051	·2350
Mianwali soil					
1	·0446	·0624	·0670	·0669	·0900
2	·0410	·0166	·0576	·0615	·0500
3	·0387	·0156	·0543	·0582	·0425
4	·0329	·0129	·0458	·0494	·0350
5	·0288	·0121	·0409	·0432	·0325

TABLE II—*contd.*

Depth	Acids	Bases	Total salts	Acids × 1·5	Total solids by evaporation
Makrera soil					
1	·0565	·0257	·0822	·0848	·0800
2	·0725	·0353	·1078	·1088	·1185
3	·1410	·0744	·0154	·2115	·2430
4	·1924	·1049	·2973	·2886	·3210
5	·1726	·0906	·2632	·2589	·2620
Nandayal soil					
1	·1005	·0451	·1456	·1508	·1550
2	·1033	·0439	·1472	·1550	·1400
3	·1460	·0685	·2145	·2190	·2025
4	·1585	·0737	·2322	·2378	·2250
5	·2114	·1004	·3118	·3171	·2900
Nagpur soil					
1	·0516	·0201	·0717	·0774	·0700
2	·0379	·0136	·0515	·0569	·0500
3	·0408	·0147	·0555	·0612	·0425
4	·0466	·0156	·0586	·0650	·0475
5	·0486	·0183	·0669	·0729	·0550
Padegaon soil					
1	·0609	·0375	·1084	·1064	·0950
2	·0837	·0357	·1194	·1256	·0950
3	·0933	·0414	·1347	·1500	·1125
4	·2598	·1205	·3803	·2897	·3725
5	·0924	·4193	1·3717	1·4286	1·5075
Padrauna soil					
1	·0656	·0315	·0976	·0978	·0905
2	·0303	·0097	·0402	·0455	·0300
3	·0713	·0402	·1115	·1070	·1025
4	·0330	·0166	·0496	·0495	·0400
5	·0457	·0223	·0680	·0686	·0505
Powerkhera soil					
1	·0327	·0117	·0444	·0491	·0440
2	·0319	·0111	·0430	·0478	·0385
3	·0276	·0100	·0375	·0376	·0400
4	·0310	·0103	·0413	·0465	·0430
5	·0355	·0174	·0529	·0533	·0425
6	..	..	..	..	..
Peshawar soil					
1	·1149	·0475	·1623	·1724	·1750
2	·0882	·0370	·1252	·1323	·1450
3	·0462	·0154	·0616	·0693	·0700
4	·0430	·0135	·0565	·0645	·0600
5	·0376	·0130	·0506	·0564	·0500
Pusa soil					
Punjab Field soil	·0450	·0156	·0606	·0675	·0475
Mysore field soil	·0754	·0273	·1027	·1131	·1150
Nepal field soil	·0451	·0163	·0614	·0677	·0475
2	·0345	·0123	·0468	·0518	·0550
3	·0420	·0151	·0571	·0630	·0675
4	·0403	·0142	·0545	·0605	·0700
5	·0351	·0126	·0477	·0527	·0550
Ranchi soil					
1	·0475	·0301	·0776	·0710	·0930
2	·0110	·0054	·0164	·0165	·0160
3	·0367	·0205	·0572	·0551	·0680
4	·0335	·0176	·0511	·0503	·0635
5	·0406	·0229	·0635	·0609	·0865

TABLE II—*contd.*

Depth	Acids	Bases	Total salts	Acids × 1·5	Total solids by evaporation
Sakrand soil					
1	·0709	·0276	·0985	·1064	·1290
2	·0608	·0289	·0897	·0912	·0840
3	·1110	·0555	·1669	·1665	·1795
4	·4134	·2250	·6384	·6201	·7485
5	·5577	·2227	·7804	·8144	·8315
Sahjahanpur soil					
1	·0216	·0079	·0295	·0324	·0245
2	·0171	·0053	·0224	·0257	·0200
3	·0172	·0063	·0235	·0258	·0290
4	·0183	·0062	·0245	·0275	·0325
5	·0130	·0048	·0178	·0195	·0150
Sylhet soil					
1	·0142	·0062	·0204	·0213	·0385
Samalkot soil					
1	·0683	·0342	·1025	·1025	·1100
2	·0820	·0421	·1241	·1230	·1750
3	·0632	·0358	·0990	·0948	·1550
Tabiji soil					
1	·0446	·0195	·0642	·0669	·0675
2	·0775	·0387	·1162	·1165	·1275
3	·0773	·0394	·1167	·1162	·1050
4	·0890	·0438	·1328	·1335	·1125
5	·0463	·0212	·0675	·0695	·0500
Taliparamba soil					
1	·0270	·0133	·0403	·0405	·0700
2	·0316	·0137	·0453	·0474	·0600
3	·0277	·0132	·0409	·0416	·0500
4	·0264	·0124	·0388	·0396	·0450
5	·0230	·0113	·0343	·0345	·0325
Waraseoni soil					
1	·0398	·0188	·0586	·0597	·0675
2	·0174	·0078	·0252	·0261	·0225
3	·0267	·0128	·0395	·0401	·0325
4	·0255	·0118	·0373	·0383	·0250
5	·0396	·0167	·0563	·0594	·0725

DISCUSSION OF THE RESULTS

The detailed results are given in Tables II and III. Table II deals with the results of analysis of soil extracts and Table III of waters. The closeness of the values, acids ×1·5, to the actual sum of salts in solution will be evident in both the cases. The discrepancies between the total solids and total salts are also apparent.

During the detailed analysis of an aqueous solution of salts, therefore, the whole procedure for determination of total solids may be omitted and the value obtained by multiplying the sum of acids by 1·5. The estimation of Na by difference involves a long chain of calculations and instead of summing up the salts including the sodium salts the whole procedure can be very much simplified.

It is equally useful in cases where only total solid figure is required. It may be noted that the determination of acid radicals except nitrates are all volumetric and involves very little time. Nitrates are generally not found in appreciable quantities in waters and soil extracts. Even determination of nitrates is much less time consuming than the total solid determination by the evaporation.

The method can be used not only for the estimation of total solids in aqueous solution but also for checking the total solid figure if the other figures of analyses are already available. From numerous results, the excellent agreement between acids×1·5 and the total solids suggests its use as a rapid means of checking water analysis results.

Other commonly used methods of estimation of total solids are by electrical conductivity [Puri

TABLE III

Results of water analysis

Description	Laboratory No.	Total solids by evaporation	Total salts	Acids × 1·5
Well water from Bharatpur	195/1937	0·1997	0·2158	0·2210
Water from Solon Brewery	296/1937	0·0642	0·0581	0·0640
Tube well water, Delhi Sahdara	427/1938	0·2708	0·2662	0·2617
Well water, Baroda	215/1938	0·0592	0·0643	0·0631
Water from Solon Brewery	221/1938	0·0818	0·0685	0·0770
Well water, Karnal	100/1939	0·0540	0·0732	0·0837
West Jumna Canal, Karnal	101/1939	0·0180	0·0218	0·0249
Tap water, Delhi	184/1939	0·0240	0·0294	0·0299
Well water, Baroda	21/1939	0·0600	0·0898	0·0905
Ground boring, Patiala	203/1939	0·0878	0·1003	0·1026
40 ft. deep well, Patiala	202/1939	0·0991	0·1183	0·1209
Tube well water, New Delhi	590/1940	0·1720	0·2401	0·2609
Well water, Najafgarh, Delhi	1032/1940	0·1200	0·1361	0·1443
Well water, Dindarpore Village, Delhi	1077/1940	0·1220	0·1440	0·1589
Well water, North Monghyr	1130/1940	0·0205	0·0263	0·0280
Well water from the Dairy, Imperial Agricultural Research Institute, New Delhi.	804/1941	0·1010	0·1064	0·1056
Well water, Indraprastha Girls College, Delhi	858/1941	0·8530	0·4882	0·4796
Well water, Alwar State	232/1942	0·1255	..	0·1714
Well water, Lady Hardinge Medical College, New Delhi	66/1943	0·1200	0·0922	0·0986
Well water, Ajmer-Merwara	120/1944	0·5073	0·5006	0·4769

and Anand, 1937] and special type of hydrometers [Puri, 1933]. All these require handling of special apparatus with usual restrictions for concentration of solutes. For simplicity, rapidity and reasonable reliability the present method may be used with confidence in the laboratory, specially where costly apparatus are not available.

SUMMARY

It has been noticed that acid and basic radicals of a salt or a mixture of salts usually remain in the ratio 2 : 1 so that the sum of acid radicals CO_3, HCO_3, SO_4, Cl, NO_3 when multiplied by 1·5 gives the total amount of solutes in solution.

This method of estimation of total salts had been tried in the case of a large number of soil extracts and waters. The agreement between analytical and calculated values had been found to be excellent.

The method of calculation of total solids by multiplying the sum of acids by 1·5 is being recommended for general routine use in laboratories.

ACKNOWLEDGEMENTS

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REVIEW

A SOURCE BOOK OF AGRICULTURAL CHEMISTRY. By Charles A. Browne (Chronica Botanica. Volume 8, Number 1, Issued Spring, 1944, Price $ 5·00)

The book as its title indicates gives an account of the development of agricultural chemistry up to the time of Leibig and contains long illustrative quotations from original sources. The author's interest and experience in chemistry have been wide and the book not only gives the 'sources' in a useful form for building up the history of agricultural chemistry but also of chemical science itself up to the period mentioned above. It is a compendium of the contributions of individual contributors recorded in a chronological manner. Those interested in the history of chemistry and of agricultural chemistry must thank the author for the great pains he has taken to make available to them this valuable information within 280 pages. All interested in the history of chemistry in general and agricultural chemistry in particular will find the book immensely helpful.

With the rapid progress of science in all its branches it is necessary to define the scope of the different branches in view of the overlap that often develops. The author's definition is as follows: 'Agricultural chemistry' is the 'chemistry of farm operations'; more specifically it is 'that branch of applied science which deals with the chemical composition and mutual chemical relations of soils, fertilizers, crops, and farm animals in so far as they concern the production upon the farm of agricultural supplies. The chemical role of the atmosphere and water in their relations to crop production.....The chemistry of the plant's contact with the three environmental agencies of earth, water, and air is the central dominant fact of all agriculture..... The mutual relationships of crops to animals and of animals to crops constitute, however, such an important part of agricultural science that they must be considered in any comprehensive treatise of agricultural chemistry.

The utilization upon the farm of agricultural raw materials for the production of butter, cheese, cider, wine, essential oils, sirup, honey, sugar, preserves, etc. is considered by some as a part of the legitimate field of agricultural chemistry and this may be allowed in so far as these pursuits form an integral part of the farm operations.'

It seems that the author is not so familiar with the contribution of India, China and Arabia to chemistry and agriculture in ancient times. There are a number of publications in English. The History of Hindu Chemistry by the late Sir P. C. Ray is a very valuable book but perhaps the long Sanskrit quotations constitute difficulty with persons not familiar with the language. As the late Svante Arrhenius pointed out in an English publication the Iatro chemical period probably owed its origin to the knowledge of chemistry of the Hindus transferred to Europe through the Arabs who mingled it with the heritages of Egypt and Greece and their own contributions. The knowledge of chemistry and agriculture characteristic of the period up to the 15th century A.D. was widely spread over India, Iran, Arabia and Europe; and the theories, superstitions, and the mixture of reason and unreason have a large common denominator. The concept of the five elements was known much earlier to the Indo-Aryans than to the Greeks and the atomistic theory was also more elaborately developed by the former earlier.

The reviewer has been told by a reputed Italian Doctor who has studied the history of medicine that the God of medicine is the only Greek God represented to have a head dress which is characteristic even of India to-day. Besides he carries a long stick with a snake coiling round it. His opinion was that these signs pointed to the Indian origin of medicine. Be that as it may, there is much field for investigation in the interchange of early scientific facts and doctrines and culture between China, India, Iran, Arabia, Asia Minor, Egypt and other countries bordering the Mediterranean.

The book covers the period from 640 B.C. up to Leibig's contributions. [J. N. M.]

PLANT QUARANTINE NOTIFICATIONS

Notification No. F. 15-1/45-A., dated the 25th September 1945 of the Government of India in the Department of Agriculture.

In exercise of the powers conferred by Section 4A of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to prohibit the export of apples, pears and quinces from British Baluchistan to any other Province in British India, except after fumigation at Quetta in accordance with such rules as may be issued by the Chief Commissioner, Baluchistan, in this behalf, under sub-section (1) of section 5 of the said Act.

Notification No. F. 16-1/45-A., dated the 25th September 1945 of the Government of India in the Department of Agriculture.

In exercise of the powers conferred by sub-section (1) of section 3 of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to prohibit the import of apples, pears and quinces from Afghanistan into British India via British Baluchistan, except after fumigation at Chaman in accordance with such rules as may be issued by the Chief Commissioner, Baluchistan, in this behalf, under sub-section (1) of section 5 of the said Act.

MGIPC—M—III-1-1—11-9-46—600.

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In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References to literature, arranged alphabetically according to author's names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state ' Original not seen '.

Sources of information should be specifically acknowledged.

As the format of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{8}$ in. $\times 9\frac{5}{8}$ in. cut), no text-figure, when printed, should exceed $4\frac{1}{2}$ in. $\times$ 5 in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{3}{4}$ in. $\times 8$ in. exclusive of that for letter press printing.

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